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Ritualistic Use of Mercury – Simulation: A Preliminary Investigation of Metallic Mercury Vapor Fate and Transport in a Trailer

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Ritualistic Use of Mercury Simulation: A Preliminary Investigation of Metallic Mercury Vapor Fate and Transport in a Trailer

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Prepared for:
Suzanne Wells, Director
Community Involvement and Outreach Center
Office of Superfund Remediation and Technology Innovation
U.S. Environmental Protection Agency
Washington, DC

Prepared by:
Raj Singhvi
Environmental Response Team
Office of Superfund Remediation and Technology Innovation
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Edison, NJ 08837

In conjunction with:
Yash Mehra, Jay Patel, Dennis Miller, and Dennis Kalnicky
Lockheed Martin/REAC
Edison, NJ 08837

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PROJECT TEAM:

USEPA/OSWER/OSRTI/ ERT, Edison, NJ
Raj Singhvi

Lockheed Martin / REAC, Edison, NJ
Dennis Kalnicky
Yash Mehra
Dennis Miller
Jay Patel
Amy Dubois
Charles Gasser
Donna Getty
Cindy Kleiman
Philip Solinski
Miguel Trespalacios

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Reviewers

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Andre P. Zownir, USEPA/ERT

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

FIGURES

FIGURES (continued)

Page No.

FIGURES (continued)

FIGURES (continued)

Page No.

TABLES

PHOTOGRAPHS

ACRONYMS AND ABBREVIATIONS

ATSDR	Agency for Toxic Substances and Disease Registry
avg	average
BM	box model
$C_d(t)$	decay model concentration
cfm	cubic feet per minute
cm	centimeter
C(t)	concentration at time t
CVAA	cold vapor atomic absorption
D	exponential decay factor
e	base of natural logarithm
E	final equilibrium concentration
ERT	Environmental Response Team
Hg	mercury
ID	interior diameter
L/min	liter per minute
mg	milligram
mL	milliliter
MRL	minimal risk level
ng/m^3	nanogram per cubic meter
NIOSH	National Institute of Occupational Safety and Health
nm	nanometer
OD	outer diameter
PTFE	polytetrafluoroethylene
Q	air flow rate from room
REAC	Response, Engineering, and Analytical Contract
RfC	reference concentration
S	rate of evaporation
S′	average emission rate
S_{avg}	average evaporation rate
SOP	Standard Operating Procedure
t	time
U.S.	United States
U.S. EPA	United States Environmental Protection Agency
μg/hr/cm^2	microgram per hour per square centimeter
μg/m^3	microgram per cubic meter
UV	ultraviolet
V	room volume
° F	degree Fahrenheit
#	number
r^2	Correlation coefficient

Executive Summary

This study was performed by the members of United States Environmental Protection Agency's Environmental Response Team (USEPA/ERT) and the Response, Engineering, and Analytical Contract (REAC) to follow up on the recommendations of the Task Force on Ritualistic Uses of Mercury Report (USEPA, 2002). The objectives of this study were to assess the fate and transport of mercury vapors associated with cultural uses of elemental mercury, and evaluate real-time mercury vapor monitoring instruments results vs. modified National Institute for Occupational Safety and Health (NIOSH) Method 6009. Data collected in this study were also used to develop models to predict indoor air concentrations and vapor residence times.

Some members of Latin American and Caribbean communities in the United States use metallic (elemental) mercury, called *azogue* or *vi dajan*, in religious rituals in the home to ward off evil spirits and to bring good luck. Mercury is also used in folk remedies. These cultural, medicinal, and religious practices may lead to acute or chronic exposure of residents to mercury, a known toxin.

The ERT simulated the following scenarios where mercury might be spilled in a home:

$ Spilling or sprinkling of 2-15 grams of elemental mercury on a carpet in a small room and a large room in a trailer;
$ Placement of different weights of mercury inside two candles to determine the relative importance of weight vs. surface area on mercury vapor concentration;
$ Spillage of mercury from a broken thermometer on a carpet in a small room;
$ Shaking of mercury beads to simulate mercury disturbance by household activities such as children playing.

Lumex RA915+ and Tracker 3000 portable mercury analyzers were used to measure real-time indoor air mercury concentrations. Real-time monitoring results were compared with air sample results obtained from modified NIOSH Method 6009. Two factory-calibrated Tracker mercury analyzers were evaluated. The monitoring results for one of the analyzers were comparable to modified NIOSH Method 6009 results, whereas the monitoring results for the other Tracker mercury analyzer were slightly lower than the modified NIOSH Method 6009 concentrations. The factory-calibrated Lumex mercury analyzers consistently provided lower mercury concentrations than the modified NIOSH Method 6009 measurements. After the Lumex and Tracker mercury analyzers were recalibrated in the laboratory using a mercury vapor standard, real-time results were in good agreement with the modified NIOSH Method 6009 measurements.

The study found that intentional sprinkling of metallic mercury for ritual purposes or accidental spillage of mercury may initially produce indoor air concentrations above the Agency for Toxic Substances and Disease Registry (ATSDR) proposed residential occupancy level (the mercury level considered safe and acceptable for occupancy of a structure after a mercury spill, provided no visible metallic mercury is present and the mercury source has been removed) (ATSDR, 2001). In some cases, the initial mercury concentration in air exceeded the ATSDR-recommended indoor action level for isolation, a concentration at which measures should be taken to prevent exposure to residents.

The indoor air mercury vapor concentration was dependent upon the total exposed surface area of the mercury, the amount of mercury used, and the size of the room. The indoor air mercury concentration decreased over time and in most cases, eventually fell below the ATSDR-proposed residential occupancy level. Increases in indoor air mercury concentration were observed when the elemental mercury source was physically disturbed or shaken, additional mercury was added, physical activity occurred near the source, or when temperatures exceeded 90°F. Periodic application of a small amount of mercury for a sustained period of time within the same enclosure could lead to chronic mercury vapor exposure above the residential occupancy level. The potential health risks of this practice were not explored in this study but warrant further investigation.

A decay model was developed to empirically describe airborne mercury concentration as a function of the evaporation of an elemental mercury source over time. Overall, the model is adequate for describing elemental mercury emissions, provided all environmental factors are stable (constant). The environmental factors include temperature, ambient pressure and electrostatic effects. In addition, the elemental mercury source must be undisturbed. The empirical model cannot predict the final equilibrium mercury concentration due to the lack of data for elemental mercury oxidation as a function of time, temperature, etc. Emission rate modeling indicates that after an increase to a maximum value, mercury vapor concentration continuously decreases to a final level typically less than 5 percent of the maximum concentration level after 50-60 hours, assuming stable, undisturbed elemental mercury vaporization.

A second model was developed to provide an order of magnitude estimate of the average mercury vapor concentration in indoor air based on average emission over various time intervals (24-hour to 4-week periods). This approach is based on periodic activity in a room producing additional mercury emissions and is adequate for predicting average mercury concentrations for the small room. The model may not be appropriate for other situations where mercury beads are disturbed on a regular basis, or are repeatedly applied.

1.0 Introduction

This study was conducted in response to a request from USEPA Headquarters to provide additional information on the fate and transport of mercury vapor to the Task Force on Ritualistic Uses of Mercury (USEPA, 2002). The primary purpose of this study was to determine the fate and transport of mercury under various experimental conditions designed to simulate the ritual use of mercury at home. The specific objectives of the study were to provide estimates of variables influencing the fate and transport behavior of mercury vapors in residential settings, and to provide estimates of potential residential exposures to small quantities of mercury from accidental or intentional spills (for example, thermometer breakage and ritual use). In order to accomplish these objectives, a trailer simulating a home environment was set up at the USEPA/ERT facility in Edison, New Jersey. Mercury vapor measurements from real-time monitoring instruments were compared with the results of air sample analyses using modified NIOSH Method 6009 (Singhvi et al., 1999). USEPA/ERT and REAC personnel conducted this study from January 14, 2002 through March 27, 2003.

Mercury occurs naturally in the environment as mercuric sulfide (cinnabar). Cinnabar has been refined for its mercury content since the 15th century. Elemental mercury is a silvery white metal, liquid at room temperature, which easily breaks up into many small droplets and evaporates to form toxic, colorless and odorless mercury vapor. The physical and chemical properties of elemental mercury are presented in Table 1. (Note that the critical information for determining vaporization and oxidation rates for liquid mercury is not available in the literature.)

Elemental mercury was formerly used in Chinese folk medicines. It was also used as an antiseptic (mercurochrome) to disinfect wounds and as a skin cream additive in the United States. Some members of Latin American and Caribbean communities in the United States use mercury *(azogue* or *vi dajan)* in religious rituals in the home, to ward off evil spirits and to bring good luck (see Photographs 1 and 2). Also, South American and Asian populations still use mercury in folk remedies for chronic stomach disorders.

Mercury spills are difficult to clean up. Routine household cleaning methods, such as sweeping or vacuuming, may worsen the problem by breaking mercury into smaller beads and dispersing it into larger areas. Tiny beads of mercury that settle into floor cracks may remain undetected, requiring the use of sealants and/or removal of flooring material to prevent mercury vapor release. Certain household surfaces, such as carpeting, cannot be effectively remediated and must be removed. Thus, improperly cleaned accidental spills and the deliberate use of mercury in cultural, medicinal, and religious practices may lead to acute or chronic mercury exposure of residents, with possible detrimental health effects. Exposure to elemental mercury may occur from breathing air contaminated with mercury vapor, and to a lesser extent, from skin absorption when handling liquid mercury, or from consuming mercury-contaminated foods or liquids. Exposure to sufficiently high levels of elemental mercury can cause permanent damage to the brain and nervous system, kidneys and developing fetus. Mercury affects many different brain functions and a variety of symptoms may occur. These include personality changes (irritability, shyness, and nervousness), tremors, changes in vision or hearing, loss of sensation, and difficulties with memory. Short-term exposure to high levels of mercury vapor in the air can damage the lungs, cause nausea, vomiting or diarrhea; produce increased blood pressure or heart rate, and cause skin rashes or eye irritation.

The ATSDR has proposed a residential occupancy level of 1.0 microgram per cubic meter of air (µg/m^3) as the mercury level considered "safe and acceptable" for occupancy of any structure after a spill, provided no visible metallic mercury is present (ATSDR, 2001). ATSDR has also recommended an indoor air action level of 10 µg/m^3 at which measures should be taken to isolate residents from potential mercury exposure; this concentration approaches levels reported in the literature to cause subtle human health effects. Assuming acute (short-term) exposure, this action level "allows for interventions before health effects would be expected" (ATSDR, 2001). Both the ATSDR (2000) and the USEPA (2004) have derived lower values that are estimates of the chronic (long-term) daily human exposure that is likely to be without appreciable risk of adverse, non-cancer health effects (ATSDR chronic minimal risk level, or MRL, of 0.2 µg/m^3; USEPA reference concentration, or RfC, of 0.3 µg/m^3). The mercury concentrations measured in this study changed rapidly over time and would not represent chronic exposure concentrations; therefore, the measured levels were compared with the proposed residential occupancy level and/or action level.

2.0 Mercury Vapor Monitoring and Sample Analysis Methodology

Modified NIOSH Method 6009 and real-time monitoring instruments were employed to measure the metallic mercury vapor concentration in the trailer. Real-time mercury vapor measurements were logged to data files at regular intervals (typically 2-15 seconds). The real-time mercury analysis results were then averaged over the appropriate period (typically 2, 4, or 8 hours) that coincided with the indoor air sample collection time. Initially, two sampling locations (in the middle of the room and one close to the source) were selected at 2.5-3.0 feet above the floor to measure metallic mercury vapor concentrations using modified NIOSH Method 6009. There were no significant differences between the mercury vapor concentrations in air samples from both locations during the same monitoring period in the small room. Therefore, it was decided to monitor mercury vapor concentrations in the middle of the small room for all subsequent experiments. Likewise, the air samples from two locations in the large room consistently had the same mercury concentrations; therefore, only one location was subsequently used for mercury monitoring in the large room. The height of 2.5-3.0 feet was considered an appropriate sampling height for residential exposure via inhalation. Other experiments performed in a small room in the trailer with fans turned on/off showed no significant difference in mercury vapor concentrations measured at sampling heights of 6 inches vs.7 feet. This does not address the possibility of direct contact with mercury beads.

2.1 Laboratory Analysis (Modified NIOSH Method 6009)

Sampling and analysis for mercury in air were conducted using modified NIOSH Method 6009, as described in REAC Standard Operating Procedure (SOP) #1827, *Analysis of Mercury in Air with a Modified NIOSH Method 6009* (USEPA/ERT, 2001). The sampling train consisted of a 200-milligram (mg) hopcalite sorbent tube connected to a personal sampling pump (SKC). Sampling times and volumes are reported with the mercury results. The sorbent material from the collection tube (typically 200 mg in a single section) is quantitatively transferred to a 100-milliliter (mL) volumetric flask. The sample is digested with 2.5 mL of concentrated nitric acid followed by 2.5 mL of concentrated hydrochloric acid. After digestion, the sample is diluted to volume with deionized water and analyzed using cold vapor atomic absorption (CVAA) spectroscopy techniques. Mercury results are reported in μg/m^3 based on the total volume of the air sample. The modified NIOSH Method 6009 incorporates more concentrated sample solutions than those of the standard method. This minimizes dilution effects while providing lower detection limits to meet the demanding measurement requirements associated with emergency response situations or mercury cleanup actions. The method is simple, rapid, and relatively free of matrix interferences.

2.2 Real-Time Monitoring

Lumex RA915$^+$: The Lumex (Ohio Lumex Co., Inc., 2000) is a portable atomic absorption spectrometer designed to detect extremely low mercury vapor concentrations and perform fast and simple analyses both at a fixed laboratory and in the field. Two modes of operation are available for ambient air analysis: AON STREAM@ and AMONITORING@. During this study, the AMONITORING@ mode was used to collect all the data. All measurements were logged to data files using an external computer. At a sample rate of 15-17 liters per minute (L/min), the Lumex can detect mercury vapor in ambient air at concentrations as low as 2 nano gram per cubic meter (ng/m^3). The low mercury detection limit and high instrument sensitivity are achieved through a combination of a 10-meter multi-path optical cell and Zeeman atomic absorption spectrometry using high frequency modulation of polarized light. The Lumex is factory calibrated (from 1000 to 40,000 ng/m^3) and mercury vapor results are reported in ng/m^3.

Mercury Tracker 3000: The Tracker (Mercury Instruments Analytical Technologies 2000) is a portable instrument based on resonance absorption of mercury atoms at a wavelength of 253.7 nanometers (nm). A membrane pump draws the mercury sample through a one-micron polytetrafluoroethylene (PTFE) filter, at a rate of approximately 1.2 L/min, into the optical cell of the instrument. Radiation from a mercury lamp passes through the cell and is measured by a solid-state ultraviolet (UV) detector. The attenuation of the UV light reaching the detector depends on the number of mercury atoms in the optical cell. The internal computer performs the quantitative evaluation of the mercury concentration in the sample in real time. The Tracker has built-in data logger capabilities and the data were downloaded after collection using an external computer. The Tracker is factory calibrated (from 60 to 300 μg/m^3) and mercury vapor concentration is reported in μg/m^3.

3.0 Experimental Design

The mercury fate and transport study was conducted in a trailer (35' x 9' 4" x 8') divided into two rooms, a small room measuring 12' x 9' 4" x 8' and a larger room measuring 23' x 9' 4" x 8' (Figure I). The small room has three windows (each 45" x 27"), one light fixture equipped with four 40-watt, 48 inches long tube light. The room was furnished with two sofas, an end table, lamp, coffee table, two fans, and drapes to simulate a small living room. Metallic mercury vapor concentrations in air were measured using the modified NIOSH Method 6009 and real-time monitoring instruments, as previously described. Temperature and humidity were monitored with an Omegaette SE 310 data logger. A Gray Wolf sensing probe was also used as a backup to record temperature and humidity. Air and wipe samples were taken in both trailer rooms before the start of the experiments to ensure the absence of mercury vapor. Similar sampling was done at the end of each experiment to verify that the trailer rooms were not contaminated with mercury vapors before the next experiment was started.

Clayton Group Services (2004) measured trailer air movement via the release of smoke. Leak testing was performed using sulfur hexafluoride tracer gas, and ventilation and air exchange rates were measured using carbon dioxide.

Several experiments were conducted to obtain information about the effect of surface area, regeneration of the mercury surface area, bead size mercury, number of mercury beads, residence time and air movement on mercury vapor concentrations. Fans were used to increase air movement; however, even with fans turned off, there was always air movement in the rooms due to the use of the Lumex and Tracker instruments, which draw air at a combined rate of 16-18 L/min. An experiment was also performed to compare the results obtained from real-time mercury vapor measuring instrumentation and modified NIOSH Method 6009. Although most of the experiments were conducted in the small room of the trailer, additional work was performed to evaluate mercury vapor concentrations in the larger room. Experiments were performed to determine whether a model could be developed to estimate mercury vapor concentration. A summary of the experimental design and aim of each experiment is provided in Table 2. Photographs 3 through 15 show the experimental setting and procedures.

An important goal of the study was to simulate the use of mercury for ritual purposes. A team member contacted a practitioner to determine how mercury is used in rituals in the home. Based on the information received, Experiment #1 was designed to simulate the ritual uses of mercury and determine the mercury vapor concentration in the small room representing one room in a home. Experiment #2 measured the effect of air movement over mercury beads on resulting mercury concentrations in air.

The third experiment measured mercury vapor concentrations after the breaking of a mercury-containing thermometer. In the fourth experiment, two different weights of mercury were placed in cavities with identical interior diameter with different depths in candles to assess whether the resulting metallic mercury vapor concentration in the room would be more dependent upon the weight of the mercury or upon bead surface area. The candle was not lit during this experiment, as it would be during ritual use. In Experiment #5, two different sizes of mercury beads were placed in a weighing dish and used to evaluate the emission of mercury vapor. During Experiment #6, two different sizes of mercury beads were placed on a shaker in a plastic weighing dish to evaluate the effect of regeneration of mercury bead surface area on concentrations in air.

Experiment #7 was performed in the larger room by initially placing 1 gram of mercury in a plastic container and incrementally adding 4 and 5 grams of mercury to obtain a total of 10.0

grams of mercury on Day 21. This experiment was performed to simulate repeated ritual applications of mercury using larger amounts (greater number of beads) in a larger room.

Experiment #8 was conducted to determine mercury vapor emission rates so that mercury residence times could be calculated. Experiment #9 was performed to compare NIOSH Method 6009 measurements and real-time mercury vapor monitoring results. And finally, Experiment #10 was performed to investigate the significant difference observed between Lumex real-time monitoring results and NIOSH Method 6009 measurements, and determine potential solutions to mitigate these discrepancies.

The detailed results of these experiments are discussed in Section 4, and graphically depicted in Figures 1-26. Results are also presented in tabular form in Appendix A. For the sake of clarity, the following sections present amounts of mercury rounded to hundredths of gram. Actual amounts used are shown in the figures and data tables.

4.0 Detailed Experiment Descriptions and Results

4.1 Simulation of Ritualistic Uses of Mercury in a Home: Experiments #1 and #2

4.1.1 Experiment #1

Mercury (2.12 grams) was dropped from a height of 3.5 feet onto a piece of carpet placed in a plastic tray in the small room. A cardboard box open at both ends was placed in the tray to ensure that no mercury could splash out of the plastic tray. The original mercury bead broke up into several smaller beads upon contact with the carpet. Air sampling pumps were placed near the plastic tray and in the middle of the room next to the coffee table. The concentration of mercury in the air samples was determined using modified NIOSH Method 6009.

There were no significant differences between mercury concentrations in air samples collected near the coffee table or near the tray. Mercury vapor concentrations decreased during each day of the experiment, from 2.8 $\mu g/m^3$ (seven-hour air sample) to 0.27 $\mu g/m^3$ (101-hour air sample) as shown in Figure 1. The mercury vapor concentration measured in the large room during Experiment #1 was lower than that in the small room as expected due to the greater distance from the mercury source and the closed door between the small room and the large room. The experiment was interrupted and the plastic tray was covered at the end of Day 5 due to departure of staff for emergency response work. Ten days later the experiment was re-started. The cover was removed and the plastic tray was gently shaken. The mercury vapor concentration gradually decreased from 1.2 to 0.40 $\mu g/m^3$ over a 16-hour period. Since the air samples collected from two separate locations in the small room and the two locations in the large room consistently had similar mercury concentrations, it was decided to collect only one air sample in each room.

To determine the effect of disturbance of the mercury beads, the plastic tray was gently shaken. Each time, the mercury concentration initially increased and then quickly decreased, eventually falling below detection limits. Subsequent gentle shaking of the tray caused the concentration of mercury vapor to increase from below detection limits (<0.11) to 0.55 $\mu g/m^3$ (seven-hour air sample); after additional shaking, the mercury vapor concentration was 1.7 $\mu g/m^3$ (seven-hour air sample).

An additional 2.6 grams (4.72 grams total) of mercury was dropped from a height of 3 feet onto the piece of carpet in the plastic tray. Fine beads of mercury were observed on the carpet. Both the modified NIOSH method and the Mercury Tracker 3000 instrument were used to measure airborne mercury vapors over a period of two days. The concentration of mercury vapor in the small room was 5.5 $\mu g/m^3$ after eight hours and decreased to 1.4 $\mu g/m^3$ at 26 hours (modified NIOSH method); the mercury vapor concentration was 0.60 $\mu g/m^3$ at 26 hours (real-time monitoring) in the large room of the trailer. The decreasing trend of mercury concentration for the small room is shown in Figure 2.

An additional 5.2 grams (9.92 grams total) of mercury were dropped from a height of 3 feet onto the piece of carpet in the plastic tray. With both fans turned off, real-time monitoring results with the Tracker mercury analyzer showed an initial mercury concentration of 38 $\mu g/m^3$, greater than both the ATSDR-recommended action level and residential occupancy level; it then continuously decreased to a concentration below the residential occupancy level. Over a 138-hour time period it decreased to 0.69 $\mu g/m^3$. When both fans were turned on, the mercury concentration increased from 0.69 to 3.4 $\mu g/m^3$ over a 20-hour period, presumably due to exposure of fresh mercury surface area by air movement across the surface of the mercury beads. Figure 3 summarizes the Tracker mercury monitoring data.

For the next series of tests, an additional 5.1 grams (15.02 grams total) of mercury were dropped from a height of 3 feet onto the piece of carpet in the plastic tray. Initially, the Tracker showed a sharp rise in mercury concentration to 139 $\mu g/m^3$ at three hours (well above both the ATSDR action level and residential occupancy level). Over a period of 46 hours, the mercury level decreased to 4.4 $\mu g/m^3$, with both fans turned on. On Day 3, the plastic tray was gently shaken and the fans were turned off. The mercury concentration, measured using the Tracker mercury analyzer, initially increased to 14 $\mu g/m^3$ and gradually decreased to 3.4 $\mu g/m^3$ over the next 45 hours.

After 124 hours of monitoring, the fans were turned on and shaking of the tray was discontinued. The mercury concentration initially increased from 4.6 $\mu g/m^3$ to 9.2 $\mu g/m^3$; during the subsequent 22-hour monitoring and sampling period, the mercury concentration (Tracker measurements) rose to a maximum of 13.0 $\mu g/m^3$ and decreased to 7.3 $\mu g/m^3$. During this time period, mercury vapor concentrations were also measured using the NIOSH Method 6009 (Figure 4) and the Lumex portable mercury analyzer. NIOSH results were slightly higher than the Tracker results. Lumex results were lower than both the NIOSH and Tracker results.

4.1.2 Experiment #2

Two grams of mercury were placed on a fresh piece of carpet in the plastic tray. The fans were turned off. Temperature, relative humidity, and indoor air mercury concentration were monitored over a 10-day time period. At the beginning of the experiment, the mercury concentration was above the ASTDR residential occupancy level, but dropped below this level within 44 hours. The concentration of mercury gradually decreased during each monitoring period. A slight increase in mercury concentration was observed when personnel entered the small room to remove data loggers and restart the Tracker 3000 mercury analyzer to continue the experiment. The rise in mercury concentration could be due to air movement in the room causing mercury on the carpet to become airborne; movement of the mercury beads may also have increased the mercury emission rate. After 156 hours, the mercury concentration increased from 0.29 to 4.9 μg/m^3 when the fan was turned on; the mercury concentration quickly decreased to 0.26 μg/m^3 at 206 hours. The mercury vapor monitoring results are depicted in Figure 5.

4.2 Broken Clinical Thermometer Simulation: Experiment #3

In Experiment #3, a clinical thermometer was broken and the mercury (0.71 gram) was spread on a piece of carpet in the plastic tray. Mercury vapor concentration was monitored over a five-day period using a Tracker mercury analyzer (Figure 6). Initially, there was an increase in mercury concentration to a level (7.2 μg/m^3) seven times the ATSDR residential occupancy level; the mercury level decreased to 0.17 μg/m^3 at 48 hours and then fluctuated between 0.07 and 0.32 μg/m^3 for the next 68 hours. On the sixth day, the plastic tray was gently shaken and the connecting door to the large room was left open. The mercury concentration increased from 0.17 to 0.72 μg/m^3 and then gradually decreased to 0.08 μg/m^3.

An earlier study by Carpi and Chen (2001) suggested that residential mercury spills continue to make significant contributions to indoor air mercury concentrations for prolonged periods of time. However, the sampling design and methodology employed by Carpi and Chen differed substantially from that used by the USEPA/ERT. While both studies reach similar conclusions regarding the potential for ongoing exposure, these methodological differences preclude direct comparisons of results.

4.3 Effect of Surface Area Simulation: Experiments #4 and #5

In Experiment #4, 2.44 grams of mercury were placed in a small cavity, prepared by boring a 0.635 cm interior diameter and 0.794 cm outer diameter (OD) steel tube into a commercially available candle (see Photograph 9). The candle was placed on a piece of carpet in a plastic tray in the small room. Two fans were placed in the room, one on the floor and the other on the couch. The sofa fan was operated in the revolving mode, whereas the floor fan was stationary and blew directly over the mercury bead and candle. The indoor air mercury concentration measured using the Tracker mercury analyzer decreased over time from 1.7 μg/m^3 and remained at or below the ATSDR residential occupancy level of 1.0 µg/m^3 after eight hours. A light gray coating was observed on the mercury surface. The coating may be due to the formation of mercuric oxide or deposition of particulates on the surface of the mercury bead.

Next, 8.39 grams of mercury were placed in a small cavity, prepared by boring a 0.635 cm ID and 0.794 cm OD steel tube into a commercially available candle. The candle cavity was designed to contain different amounts of mercury without changing the exposed surface area. The measured indoor air mercury concentrations decreased with time and were comparable to that for the first candle. The concentrations vs. time plots were not significantly different for the two different masses of mercury with the same exposed surface area. The results of this experiment are presented in Figure 7.

It should be noted that during the ritual use of mercury-containing candles in homes, the candle is actually lit, which would be expected to increase mercury volatilization. This experiment did not examine the effect of lighting the candle.

Additional experiments were performed to determine if there was a significant change in mercury emission (concentration) using different amounts (with different surface areas) of mercury placed in a 1-square inch plastic weighing boat. During the first part of Experiment #5, 2.44 grams (1 cm diameter) of mercury were placed in the weighing boat. The connecting door between rooms was kept closed and the fans were turned on. The mercury vapor concentration in the small room decreased over time and generally remained below the residential occupancy level. An increase in mercury vapor concentration was observed when the indoor temperature in the non-airconditioned trailer approached 100^{o}F (Figure 8) during a period of high outdoor temperature.

For the second phase of Experiment #5, 2.44 grams of fresh mercury were placed in the weighing boat; the fans were turned on and the connecting door between rooms was left open to increase the volume of vapor dispersion. The mercury vapor concentrations were lower over extended time periods as expected due to the larger size of the room. The same general trend was observed; mercury vapor concentration continually decreased with time except for an occasional increase possibly due to elevated room temperature (Figure 9).

A larger amount of mercury (8.39 grams, 1.6 cm bead diameter) was placed in a 2-square inch plastic weighing dish in the small room; the connecting door was closed and the fans were turned off. Indoor air mercury concentrations were measured using the Tracker instrument. Mercury vapor concentration decreased from 3.3 to 0.18 µg/m^3 over a 48-hour time period. The fans were turned on and monitoring continued; the mercury vapor concentration increased from 0.18 to 0.42 µg/m^3 and subsequently decreased to 0.12 µg/m^3 over a 42-hour time period (Figure 10).

In the last experiment of this series, 8.38 grams of mercury, bead diameter of 1.6 cm, were placed in a 2-square inch plastic weighing dish on the carpet in the plastic tray. The connecting door was closed and the fans were turned on. Mercury vapor concentrations were monitored using the Tracker and Lumex mercury analyzers. Air samples were also collected and analyzed for mercury using modified NIOSH Method 6009. Using the Tracker instrument, the mercury vapor concentration decreased from 8.7 to 0.80 $\mu g/m^3$ over a 24-hour time period. Comparable mercury concentrations were obtained for the Tracker and Lumex analyzers; however, both monitoring instruments produced lower mercury concentrations than the NIOSH method (Figure 11). For comparable amounts of mercury with the same bead diameter, the initial (first eight hours) indoor air mercury levels were approximately two times greater with the fans turned on than with the fans turned off.

4.4 Surface Area Regeneration Simulation: Experiment #6

For Experiment #6, 0.98 grams of mercury was initially placed in a 2-square inch plastic weighing dish in a plastic tray in the small room; the fans were turned on and the connecting door was closed. The plastic tray was placed on a mechanical shaker lined with a small piece of carpet. The shaker was set to shake for just under 17 hours (999 minutes) at 100 cycles per minute. The plastic tray was secured to the shaker by duct tape.

Mercury vapor concentrations were monitored using the Lumex and Tracker mercury analyzers, and sampled and analyzed using the modified NIOSH method. The mercury vapor concentration remained relatively constant at a concentration greater than the residential occupancy level for a 16-hour time period while the shaker was on. When the shaker was stopped, the mercury vapor concentration decreased as depicted in Figure 12. Each time the shaker was restarted, the mercury vapor concentration increased. Lumex, Tracker, and NIOSH mercury results are compared in Figure 12.

Next, 9.63 grams of mercury were placed in a 2-square inch plastic weighing dish in the plastic tray in the small room; the fans were turned on and the connecting door was closed. The plastic tray was placed on a mechanical shaker lined with a small piece of carpet. The shaker was set to shake for just under 17 hours at 100 cycles per minute. The plastic tray was secured to the shaker by duct tape. The mercury vapor concentration decreased from 29 to 15 $\mu g/m^3$ (Tracker results) over a 10-hour time period (Figure 13). These concentrations exceed both the ATSDR-recommended residential occupancy level and action level. After the shaker automatically turned off, the mercury vapor concentration continuously decreased from 15 to 0.4 $\mu g/m^3$ over a 50-hour time period. The experiment continued with gentle shaking of the weighing dish. There was an initial increase in mercury vapor concentration from 0.4 to 3.8 $\mu g/m^3$ followed by a decrease to 0.18 $\mu g/m^3$ over the next 44 hours (Figure 13).

4.5 Simulation of Ritualistic Mercury Use in a Large Room

In the first phase of Experiment #7, 0.98 grams of mercury was placed in a 1-square inch plastic weighing boat on a piece of carpet in a plastic tray in the large room; the door between the small room and the large room was closed. The two fans were turned on, with one fan located about 4 feet from the plastic tray at a height of 4 feet, and the other fan 12 feet from the plastic tray. Neither fan blew air directly over the top of the plastic tray.

Mercury concentrations were measured using both the Tracker and Lumex monitoring instruments, and sampled and analyzed using the modified NIOSH Method 6009. The mercury concentration in the initial air sample collected at eight hours was 1.4 µg/m^3. The indoor air mercury concentration decreased to 0.04 µg/m^3 over a 257-hour time period. Tracker and Lumex mercury monitoring results are compared with NIOSH method measurements in Figure 14. Tracker #2, used in all previous experiments, yielded results that were consistently 10-20 percent lower than mercury measurements using the modified NIOSH method. Therefore, a second Tracker mercury analyzer (Tracker #1) was used in this experiment to determine whether the two Tracker instruments would provide consistent results, or whether Tracker #1 results would be more comparable to the NIOSH measurements.

Four additional 1-gram mercury beads totaling 4.07 grams (for a total combined weight of 5.0508 grams of mercury) were placed in individual plastic weighing boats on the piece of carpet in the plastic tray. The mercury vapor concentration in the large room (modified NIOSH Method 6009) initially increased to 5.9 µg/m^3 (six times the residential occupancy level), and then gradually decreased to below the method detection limit (0.034 µg/m^3) over a 327-hour time period. Measurements from Tracker #1, Tracker #2, Lumex, and the NIOSH results are shown in Figure 15.

Finally, five additional 1-gram beads of mercury were placed in individual plastic weighing boats in the manner described above; a total of 10.40 grams of metallic mercury was used for this experiment. The indoor air mercury vapor concentration, as per modified NIOSH Method 6009, initially increased to 4.1 µg/m^3 and then rapidly decreased to 0.17 µg/m^3 over a 40-hour time period and continued to decrease to 0.05 µg/m^3 over an additional 201-hour time period (Figure 16).

4.6 Mercury Vapor Emission Rate: Experiment #8

In Experiment #8, seven individual 0.5 cm diameter mercury beads (with a total mass of 7.0511 grams) were placed in individual 1-square inch plastic weighing boats on a piece of carpet in a plastic tray in the small trailer room. The door between the small room and the large room was closed; the fans were turned on and the airflow of one of the fans was directed at the plastic tray. Real-time monitoring was performed using a Tracker mercury analyzer. The weights of the individual beads were measured at time zero, at seven days (168 hrs) and at the end of 15 days (362 hrs). As seen in Figure 17, the indoor air mercury concentration peaked every 24 hours; mercury emission increased with temperature, with the highest temperature occurring at midday. Although this pattern continued throughout the experiment, the rate of mercury vapor emission (and corresponding concentration) decreased on each successive day. The initial indoor air mercury concentration was 12.8 µg/m^3 and gradually decreased to 0.31 µg/m^3 (362 hours).

The above experiment was repeated with seven individual 0.5 cm (1 gram) beads (total mercury weight was 7.00 grams) for four days; air samples were collected and analyzed using modified NIOSH Method 6009 and monitored using the Tracker real-time instrument. Tracker mercury monitoring results are presented in Figure 18. NIOSH method mercury concentrations are compared with time-averaged Tracker monitoring results in Figure 19. NIOSH results were consistently higher than those obtained with the Tracker analyzer. Concentrations decreased from a maximum of 13 $\mu g/m^3$ (Tracker data), but remained above the residential occupancy level.

The experiment was repeated a third time with seven 1-gram mercury beads; air samples were collected for modified NIOSH method analysis and real-time air monitoring was performed for two days using a Tracker mercury analyzer. Tracker mercury data are presented in Figure 20. Figure 21 compares time-averaged Tracker monitoring results with NIOSH method measurements. NIOSH measurements again exceeded Tracker measurements. Tracker data showed a maximum of 16 $\mu g/m^3$ four hours after placement of the beads. After 46 hours, the concentration remained above the residential occupancy level.

A single mercury bead weighing 1.11 grams was placed in a weighing dish under the same conditions as described above. Indoor air mercury concentration was monitored for two days using the Tracker #2 mercury analyzer. The single-bead emission monitoring experiment was repeated using 1.14 and 1.13 grams of mercury. Finally, indoor air mercury concentration was monitored using a Lumex mercury analyzer using single bead (1.04 grams). Real-time monitoring data for the four 1-gram single bead experiments are presented in Figure 22. The three sets of Tracker monitoring results yielded similar mercury concentration profiles; the Lumex mercury monitoring results were consistently lower than the Tracker results. Air samples were also collected for modified NIOSH Method 6009 analysis. Figure 23 compares time-averaged Tracker monitoring results with NIOSH method measurements. The single-bead experiments revealed that initial air concentrations were lower than those seen with the multiple-bead experiments; furthermore, concentrations fell to the residential occupancy level or below. Thus, the number of beads appeared to influence the resulting mercury vapor concentrations. Experiment #8 also provided information on mercury emission rates that were useful in air modeling described in Section 5.

4.7 Investigation to Determine Significant Difference between Lumex and NIOSH: Experiment #9 and #10

Comparison of real-time and modified NIOSH 6009 data from this study revealed that Lumex real-time monitoring results were consistently lower than modified NIOSH 6009 results. A similar discrepancy between the Lumex and the NIOSH 6009 results has been observed over the past three years at several mercury spill sites (Singhvi et al., 2003). In the present study, several unsuccessful attempts were made by the Lumex technical staff to resolve these differences by replacing the USEPA Lumex analyzers with different Lumex instruments. The team decided to conduct an additional experiment before investing in a gaseous mercury standard to calibrate the real-time monitoring instruments.

In Experiment #9, 10 individual 0.5-cm diameter mercury beads (with a total mass of 10.86 grams) were placed in individual 1-square inch plastic weighing boats on a piece of carpet in a plastic tray in the small room. The door between the small room and the large room was closed; the fans were turned on and the airflow of one of the fans was directed at the plastic tray. Real-time monitoring was performed using two Tracker mercury analyzers, Tracker #1 (Serial #0301/161), Tracker #2 (Serial #0301/168), and a Lumex mercury analyzer (Serial #S/N 176); air samples were also collected and analyzed using modified NIOSH Method 6009 procedures. After eight hours, the mercury vapor concentration (NIOSH method) in the small room was 6.9 $\mu g/m^3$; the mercury concentration continuously decreased to 0.40 $\mu g/m^3$ after 120 hours.

Tracker #2 mercury monitoring results were generally comparable to NIOSH measurements; Lumex monitoring results were consistently lower than the NIOSH measurements and the Tracker #2 monitoring results. Measurements provided by these different methods, in order of decreasing mercury concentration, are as follows: NIOSH measurements = Tracker #2 results > Tracker #1 results > Lumex results. Experiment #9 results are presented in Figure 24.

Statistical analysis of earlier data indicated a significant difference (approximately 50 percent) between modified NIOSH Method 6009 measurements and real-time Lumex monitoring results. Experiment #10 was conducted to evaluate these differences. The Lumex technical staff provided a loaner instrument (S/N 215) with modified software. The results from this instrument continued to be 20 percent lower than the modified NIOSH method despite the modified software. The two USEPA Lumex instruments (S/N 176, and S/N 188) were updated with the new software provided by the Lumex technical staff. A mercury vapor standard with a concentration of 5.0 $\mu g/m^3$ was obtained from Spectra Gases (Branchburg, New Jersey). A sample of the mercury vapor standard was collected and analyzed using the modified NIOSH Method 6009 to check/verify the standard concentration. The NIOSH results (5.05 and 4.97 $\mu g/m^3$) for the standard were in excellent agreement with the Spectra Gases specified concentration of 5.0 $\mu g/m^3$. The mercury concentration of the gaseous standard was then measured with both the Lumex and Tracker mercury analyzers using the setup shown in Figure 25. Time-averaged readings were used to determine the percent recovery of the standard for the individual real-time mercury analyzers. A correction factor, based on percent recovery, was then used to calculate a new calibration factor for each analyzer. The new calibration factor was entered into the analyzer memory to adjust real-time readings to agree with the mercury standard concentration (5 $\mu g/m^3$).

To evaluate the calibrated monitoring instruments, 2 grams of mercury were placed in the 1-square inch plastic weighing dish on a piece of carpet in the plastic tray in the small room; the fans were turned on and the connecting door was closed. The airflow of one fan was directed towards the plastic tray. Air samples were collected during this experiment and were analyzed using modified NIOSH Method 6009. Real-time monitoring was performed using three different Lumex instruments and two different Tracker instruments. The real-time monitoring data and NIOSH results were comparable and are presented in Figure 26. Thus, the recalibrated real-time instrument results were more consistent with those of modified NIOSH Method 6009.

5.0 Tracer Gas Studies and Ventilation Rate Measurements

Clayton Group Services (2004) performed air movement studies by releasing smoke into the trailer. Very little air movement was observed. The smoke dispersed slowly in all directions from the center of the room. Sulfur hexafluoride tracer gas was used to identify leaks from the trailer to the outside. Air exchange rates and ventilation rates were determined by measuring decay characteristics of carbon dioxide released into the space. The ventilation rate in the large room was 17.49 cubic feet per minute (cfm) with an air exchange rate of 0.659 air exchanges per hour, whereas the small room had a ventilation rate of 24.92 cfm with an air exchange rate of 1.67 air exchanges per hour. These results were used in the air modeling presented in Section 6.1. They reflect the conditions that existed at the time the measurements were made and, since the trailer is not airtight, are likely to change depending on environmental conditions such as wind speed and direction.

6.0 Empirical Model for Indoor Air Mercury Emission

Several models were developed and evaluated to empirically describe indoor air mercury vapor concentrations resulting from evaporation of an elemental mercury source. The initial evaluation was based on a simple box model presented in Riley et al (2001), which provided an order of magnitude estimate of potential mercury vapor exposure in a room resulting from cultural and religious practices.

The box model has the form:

$$C(t) = \frac{S}{Q}\left(1 - e^{-Qt/V}\right) \tag{1}$$

where,

C(t) = concentration at time t C(t) = 0 at t=0
t = time (hours)
S = rate of evaporation (micro gram per hour)
Q = air flow rate from the room (cubic meters per hour)
V = room volume (cubic meters)

The box model predicts an exponential rise in mercury vapor concentration to a final equilibrium concentration of S/Q. The rate of exponential increase is governed by the V/Q time constant which is the number of hours per air exchange; Riley, et al. (2001) suggest a typical value of two hours for V/Q. The authors acknowledge that their simple model only provides an order of magnitude estimate of potential exposure because the fate and transport of mercury vapor inside a house is complex and case-specific, and requires data for a variety of variables, including adsorption and desorption characteristics.

Examination of the voluminous data obtained using Lumex and Tracker real-time mercury vapor analyzers indicates that the simple box model does not adequately predict final equilibrium mercury concentrations. Typically, mercury concentration rises to a maximum in the first few hours and then decreases (decays) with time until the final equilibrium concentration is reached. The decay mechanism appears to be exponential in nature. Several potential decay models were evaluated.

The decay model best suited for modeling mercury emission data was:

$$C_d(t) = C(t) * \left[e^{-Dt} * \left(1 - \frac{E}{S/Q} \right) + \frac{E}{S/Q} \right] \qquad (2)$$

$$= C(t) * \left[e^{-Dt} + \left(1 - e^{-Dt} \right) * \frac{E}{S/Q} \right]$$

where,

$C_d(t)$ = decay model concentration
$C(t)$ = box model concentration
D = exponential decay factor
E = final equilibrium concentration

This model provides a smooth transition to the final equilibrium concentration and predicts concentrations that are always less than or equal to the conservative box model concentration (upper limit). The decay component of the model is consistent with the observed mercury emission (concentration) decrease with time, possibly due to oxidation of elemental mercury.

Figure 27 presents Lumex monitoring data for a 45-hour time period. The data were fit to Equation 2 using the Sigma Stat (v2.03) statistical analysis software package to perform weighted non-linear regression. The final equation, with an $r^2 = 0.998$, is as follows:

$$C_d(t) = 7121 * \left(1 - e^{-0.732(t+0.345)} \right) * \left[e^{-0.117(t+0.345)} + \left(1 - e^{-0.117(t+0.345)} \right) * \frac{140}{7121} \right]$$

The final equilibrium concentration predicted by this equation was 140 ng/m^3 (0.14 μg/m^3); this value is reasonable based on the data in Figure 27. The t + 0.345 term ($t + t_0$) accounts for time offset between time zero and the start of monitoring measurements.

Table 3 presents decay model (Equation 2) non-linear regression results for several sets of mercury concentration vs. time data (r^2 range = 0.910 to 0.998). Lumex and Tracker monitoring data, box model results and decay model calculation results are presented in Figures 27-34. The room volume was fixed at 25.37 m^3 for all nonlinear regression analyses.

The data in Table 3 show a wide range of air exchange rate (Q/V) values (0.099 to 1.54, average = 0.68) for the mercury monitoring data sets evaluated. The data in Table 3 are generally in agreement with the range of mean residential air exchanges per hour (0.53 to 1.1) noted in a National Research Council report on the risk associated with radon in drinking water (NRC, 1999), and with those (0.25-1.57) reported in a study of residential air exchange rates in the United States (Murray et al., 1995). Fit values for the "E" term indicate that the decay model final equilibrium concentration is generally 2-4 percent of the box model equilibrium value. The fit parameters for the August 19, 2002 Lumex monitoring data set (see Figures 31 and 32) may be unreliable because the time offset parameter reached the defined upper limit (0.5 hours) within the first three iterations of the regression. The August 5, 2002 Lumex monitoring data (Figure 27) and August 7, 2002 Tracker monitoring data (Figure 28) are from the same 45-hour time frame. Regression results for Q, D, and E terms are in good agreement for the two monitoring data sets. There are a number of individual Tracker or Lumex readings in Figures 27-34 that are lower than the adjacent readings on the figures. These readings are normal and occur during automatic monitoring instrument zero adjustments, and do not reflect actual measured concentrations.

Overall, this decay model (Equation 2) is adequate for describing elemental mercury emissions provided all environmental factors are stable (constant). The factors include temperature, ambient pressure, air exchange rate, and electrostatic effects. In addition, the elemental mercury source must be undisturbed. It is highly unlikely that all these conditions are met during ritualistic uses of mercury. This is evident from the observed "bumps" in the mercury concentration vs. time data sets (Figures 27-34).

The empirical decay model cannot predict the final equilibrium concentration due to the lack of data for elemental mercury oxidation as a function of time, temperature, etc. Mercury monitoring results indicate that the final equilibrium concentration is typically less than 5 percent of the simple box model predicted concentration. The final concentration appears to be reached after 50-60 hours of stable, undisturbed elemental mercury vaporization.

Figure 35 presents mercury concentration vs. time data when the mercury container was shaken for the first 16 hours. The box model appears to accurately predict mercury concentration for the first nine hours (Figure 36) before mercury emission rate decay begins. Figure 37 shows the final model with a rate decay time offset of 9.04 hours. The final model, with an $r^2 = 0.957$, is:

$$
\begin{aligned}
C(t) &= Box\ Model = BM \\
&= 7.322 * \left(1 - e^{-\left(\frac{23.49}{25.37} * (t + 0.137)\right)}\right) \\
&= 7.322 * \left(1 - e^{-(0.926 * (t + 0.137))}\right) \qquad t \langle 9.04\ hours
\end{aligned}
$$

$$C(t) = BM * \left(e^{-(0.124*(t-9.041))} * \left(1 - \frac{0.0378}{7.322}\right) + \frac{0.0378}{7.322} \right)$$

$$= BM * \left(e^{-(0.124*(t-9.041))} * (1 - 0.005163) + 0.005163 \right) \qquad t \geq 9.04 \; hours$$

where, S/Q = S/23.49 = 7.322;
therefore, S = 172 µg/hour and
the final equilibrium concentration is 0.038 µg/m^3.

6.1 Model for Predicting Average Indoor Air Mercury Concentration

Additional studies were carried out to develop a simple model to predict average mercury vapor concentrations in indoor air based on average emission over various time intervals.

Table 4 presents mercury emission rates based on weight loss from mercury beads of different diameter. Figures 38 and 39 present Tracker mercury concentration (two-hour average) vs. time data for nominal 0.5 cm beads. Figure 40 presents the non-linear regression analysis for the nominal 0.5 cm bead average mercury emission rate in micro gram per hour per square centimeter (µg/hr/cm^2) vs. time data (22-864 hours). Figure 41 includes emission rate data for nominal 0.5 cm beads and other bead sizes. Total bead surface areas were based on the effective bead diameter, which was calculated assuming a spherical bead with weight equal to the starting weight divided by the number of beads and density of 13.6 g/cm^3. The beads tend to flatten and spread out on the surface upon which they rest, therefore, the bead active emitting surface area is less than 100 percent. The fraction of bead surface area available for emission depends upon several factors including bead diameter, resting surface roughness, and surface tension. The bead active surface area for emission was assumed to be 50 percent for this study. The final model (Equation 3) can be used to predict average emission rate, S′, for 22-864 hours exposure time (r^2 = 0.943).

$$S' = avg\ \mu g / hr / cm^2 = 96.947 * \left(e^{-(0.0188 * hours)} + (-0.0000033 * hours) + 0.0968 \right) \qquad (3)$$

The nominal 0.5 cm data in the first two sections of Table 4 (first 11 data sets) were used to determine model parameters in Equation 3; the data in the last set was not included.

Table 5 lists emission rates and concentrations as calculated using Equation 3. The average predictive error (average percent difference) for the nominal 0.5 cm bead calibration data (Figure 40) was 13 percent (range 0.5-31 percent). The average predictive error for all bead sizes (Figure 41) was 40 percent (range 0.5-349 percent).

The average evaporation rate, S_{avg}, (µg/hr) is given by:

$$S_{avg} = S' * (total\ emitting\ surface\ area)$$

$$= S' * (number\ of\ beads) * (bead\ emitting\ surface\ area) \qquad (4)$$

The average concentration (μg/m^3) between t = 0 and t = t_2 based on the box model is then:

$$C_{avg} = \frac{S_{avg}}{Q} * \left(1 - \frac{1 - e^{-\frac{Q}{V} * t_2}}{\frac{Q}{V} * t_2} \right) \tag{5}$$

where, the air exchange rate, Q/V = 1.67, was based on measured values.

When the $(Q/V)*t_2$ term is very large (>100), equation 5 can be simplified to:

$$C_{avg} \approx \frac{S_{avg}}{Q} \tag{6}$$

Figure 42 shows model prediction vs. average and minimum values measured with the Tracker analyzer. The slopes of these fits were used to calculate the predicted average and minimum concentrations listed in Table 5. Figures 43 and 44 show measured vs. final predicted values for average and minimum mercury concentration. The solid line represents 1:1 correlation.

Table 6 presents the final model for emission from mercury beads (Equations 3-5). Input variables to the model include room volume, weight of mercury spilled, average mercury droplet size, air exchange rate (Q/V), and (optionally) number of hours for calculation. The minimum number of hours is 24 because the rate vs. time fit (Figure 40) applies from 22 to 864 hours. The calculation predicts average concentrations over 24-hour to four-week periods. This model works reasonably well for predicting average mercury concentrations for the small room, as shown in Table 5. It is based on measured weight loss vs. time data where there is periodic activity in the room producing additional mercury emission (Figures 38 and 39). This model only provides an order of magnitude estimate of potential exposure because the fate and transport of mercury vapor inside a house is complex and case specific, and requires data for a variety of variables including adsorption and desorption characteristics. The model may not work for other situations where the mercury beads are disturbed on a regular basis.

An Excel spreadsheet for predicting average indoor air mercury concentrations based on Equations 3 through 5 is included on the CD accompanying this report. Appendix B shows example printouts of data entry and tabulated results from this spreadsheet.

7.0 Summary of Results

The scenarios studied were:

- Spilling or sprinkling of 2-15 grams of mercury to simulate ritual sprinkling of mercury in a home;
- Placement of 2-8 grams of mercury in identical-sized cavities inside candles to determine the relative importance of weight vs. surface area on mercury vapor concentration;
- Spillage of mercury from a broken clinical thermometer;
- Shaking of mercury beads to simulate mercury disturbance by household activities, such as children playing.

In all scenarios, the mercury concentration rapidly increased during the first few hours of exposure and then generally decreased. In most experiments, the initial indoor air mercury concentration exceeded the ATSDR-suggested residential occupancy level; in some cases, the action level was also exceeded. However, the concentrations generally decreased to below the residential occupancy level. Indoor mercury concentrations increased if there was air movement over the mercury surface, if the active mercury surface was regenerated (by shaking), or if additional mercury was applied. Slight increases in mercury concentration were also observed when there was airflow movement in the room caused by human intervention, i.e., physical entry into the room, and when the room temperature exceeded 90°F.

Mercury vapor concentration was proportional to the exposed surface area and the amount of "spilled" elemental mercury, and inversely proportional to the size of the room. The indoor air mercury vapor concentration appeared to be more dependent on the size of the surface area of exposed mercury than the weight of the mercury. Similar indoor air mercury concentrations were measured after either 2 or 8 grams of mercury were placed into the same internal diameter cavity in candles, because the active surface area for evaporation (volatilization) remained the same.

During these experiments, discoloration of the bead surfaces was observed over time. This may reflect the formation of a non-volatile mercuric oxide layer and/or settling of particulates on the surface, which would reduce the surface area for evaporation (emission) and thereby lower the rate of mercury vaporization. That may explain the observed decrease of indoor air mercury concentrations from initial maximum levels. In addition, the mercury vapor in the enclosed room dissipated due to air movement and leakage from the room. When shaken, the active surface area of mercury beads appeared to be replenished, with an observed increase in mercury vapor concentration. Eventually, the refreshed surface also appeared to develop an oxide layer and/or become coated with particles.

Lumex RA915+ and Tracker 3000 real-time mercury analyzer results were compared with air sample results obtained from modified NIOSH Method 6009 analysis. Two factory-calibrated Tracker mercury analyzers were evaluated. The monitoring results for Tracker #1 mercury analyzer were slightly lower than modified NIOSH method concentrations, whereas the monitoring results for the Tracker #2 mercury analyzer were comparable to modified NIOSH method measurements. The factory-calibrated Lumex mercury analyzers consistently yielded lower mercury concentrations than modified NIOSH method measurements. After the Lumex and Tracker instruments were recalibrated in the laboratory using a mercury vapor standard, their results were more consistent with the modified NIOSH method measurements.

A model was developed to empirically describe indoor air mercury concentrations from evaporation of an elemental mercury source over time. Overall, this model is adequate for describing elemental mercury emissions provided all environmental factors are stable (constant). The factors include temperature, ambient pressure, air exchange rate, and electrostatic effects. In addition, the elemental mercury source must be undisturbed. The empirical model cannot predict the final equilibrium mercury concentration due to the lack of data for elemental mercury oxidation as a function of time, temperature, etc. Modeling results, however, indicate that the final indoor air mercury concentration is typically less than 5 percent of the box model maximum mercury concentration and, generally, the final concentration is reached after 50-60 hours of stable, undisturbed elemental mercury vaporization. The model adequately describes the decrease in mercury concentration with time observed for all experiments in this study and indicates a much lower final mercury concentration than the simple box model proposed by Riley et al. (2001).

A second model was developed to predict average mercury vapor concentration in indoor air based on average emission over various time intervals (24-hour to 4-week periods). This model is adequate for predicting average mercury concentrations for the small room. It is based on measured mercury weight loss vs. time, given periodic activity in the room that produced additional mercury emission. The model may not be appropriate for other situations where the mercury beads are disturbed on a regular basis because it does not account for all factors that may influence elemental mercury emission rates.

8.0 Conclusions and Recommendations

Mercury spills are difficult to clean up, and may be worsened by the use of ordinary household cleaning methods, such as sweeping and vacuuming. The use of sealants and/or removal of flooring material may be required to prevent the release of vapor from small, undetected beads of mercury lodged in floor cracks. Certain household surfaces, such as carpeting, cannot be effectively remediated and must be removed. This study shows that intentional ritual sprinkling of metallic mercury or accidental spillage of mercury may initially produce indoor air mercury concentrations above the ATSDR-suggested residential occupancy level, and in some cases, above the action level. When the source is undisturbed, the concentration decreases over time and generally falls below the residential occupancy level. It is unlikely, however, that mercury would remain undisturbed in a residential setting. Furthermore, periodic spillage or ritual application of a small amount of mercury for a sustained period of time within the same enclosure may lead to chronic mercury vapor exposure with possible detrimental health effects. This was not evaluated in the present study.

The study found that indoor air mercury vapor concentration was dependent upon the total exposed surface area of the mercury, the amount of mercury, and the size of the room.

Increases in indoor air mercury concentration were observed when the elemental mercury source was physically disturbed or shaken, mercury was reapplied, the room airflow was changed, opening of a door, or physical activity near the source, or when temperatures exceeded 90°F. The greatest increase in mercury vapor concentration was observed when the mercury beads (source) were constantly disturbed; presumably, shaking/agitation produced new active surface area for mercury vaporization.

The simple box model proposed by Riley et al. (2001) does not adequately describe the mercury vapor concentration over time, as observed for different experimental conditions in this study. A decay model was developed to empirically describe indoor air mercury concentration as a function of evaporation of elemental mercury over time. Mercury emission modeling indicates an initial maximum mercury vapor concentration, followed by a continuous decrease to a final concentration that is typically less than 5 percent of the box model-predicted maximum concentration; the final concentration is typically reached after 50-60 hours of stable, undisturbed elemental mercury vaporization.

An order of magnitude estimate of the average mercury vapor concentration in indoor air may be predicted based on average emission rates over various time intervals (24-hour to four-week periods). This approach is based on periodic activity in the room leading to additional mercury emission, and is adequate for predicting average mercury concentrations for the small room. This model only provides an order of magnitude estimate of potential exposure because the fate and transport of mercury vapor inside a house is complex and case specific and requires data for a variety of variables including adsorption and desorption characteristics. The model may not be appropriate for other situations where the mercury beads are disturbed on a regular basis, or where mercury is repeatedly applied. The choice of model (the model developed in this study vs. box model of Riley et al.) may greatly affect conclusions about potential health risks from mercury exposures.

In conclusion, the real-time air monitoring and analysis of air samples collected during simulated ritual uses of mercury indicate the potential for initial high exposures to mercury; long-term exposures from undisturbed sources appear to be less significant and of unknown health concern. The results of this study will be provided to the ATSDR for review and comment.

Recommendations for future work are as follows:

- If possible, obtain permission to conduct mercury monitoring under conditions of actual ritual mercury use in a home. Real-time air monitoring and air sample collection and analysis should begin within two days of mercury use and continue for 120 days.

- Perform additional experiments using different mercury bead diameters, to further evaluate the effect of surface area on vapor emission rates.

- Conduct a formal risk assessment to evaluate the risks to occupants under conditions of ritual mercury use, with emphasis on repeated mercury applications and long-term exposure.

9.0 References

Agency for Toxic Substances and Disease Registry (ATSDR) (2000). *Minimal Risk Levels (MRLs) for Hazardous Substances*. Available at www.atsdr.cdc.gov/mrls.html Accessed December 12.

ATSDR (2001). *Suggested Action Levels for Indoor Mercury Vapors in Homes or Businesses with Indoor Gas Regulators.* Attachment 2 to Illinois Department of Public Health, March 6, 2001 Health Consultation: *Residential Mercury Spills from Gas Regulators in Illinois (a/k/a NICOR), Mt. Prospect, Lake County, Illinois.*
Available at www.atsdr.cdc.gov/HAC/PHA/resmerc/nic_p1.html.

Carpi, A, and Y.F. Chen (2001). *Gaseous Elemental Mercury as an Indoor Air Pollutant.* Environmental Science and Technology 35: 4170-4173.

Clayton Group Services (2004). *Revised Report – Tracer Gas Studies – EPA Trailer*. Clayton Project No. 40-02304.00. February 19.

Mercury Instruments Analytical Technologies (2000). *Mercury Tracker 3000 Operating Manual.* March.

Murray, D.M., and D.E. Burmaster (1955). *Residential Air Exchange Rates in the United States: Empirical and Estimated Parametric Distributions by Season and Climatic Region*. 1995 Risk Analysis, 15: 459-465.

National Research Council (NRC), Committee on Risk Assessment of Exposure to Radon in Drinking Water (1999). *Risk Assessment of Radon in Drinking Water.* Washington, D.C: National Academy Press.

Ohio Lumex Co., Inc. (2000). *Lumex Multifunctional Mercury Analyzer RA-915+ Operation Manual.*

Riley, D.M., C.A Newby, T.O. Leal-Almeraz, and V.M. Thomas (2001). *Assessing Elemental Mercury Vapor Exposure from Cultural and Religious Practices.* Environmental Health Perspectives 109: 779-784.

Singhvi, R., D. Kalnicky, J Patel, and Y. Mehra (2003). *Comparison of Real-Time and Laboratory Analysis of Mercury Vapor in Indoor Air: Statistical Analysis Results.* Proceedings of the Twenty-Sixth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, 1: 439-451 (June 10-12).

Singhvi, R., D.A. Johnson, J. Patel, and P. Solinski (1999). *Analytical Method for Indoor Air Monitoring for Metallic Mercury Vapors*. Presented at the 8^{th} International Conference on Indoor Air Quality & Climate, Indoor Air 99, Edinburgh, Scotland.

United States Environmental Protection Agency (USEPA) (2004). Mercury, elemental (CASRN 7439-97-6). Integrated Risk Information System.
Available at www.epa.gov/iris/subst/0370.htm. Accessed February 4.

USEPA, Office of Emergency and Remedial Response (2002). Task Force on Ritualistic Uses of Mercury Report, OSWER 9285.4-07, EPA/540-R-01-005. December.

USEPA/Environmental Response Team Center (USEPA/ERT) (2001). Standard Operating Procedure #1827, *Analysis of Mercury in Air with a Modified NIOSH Method 6009*, Rev. 3.0. February 5.

FIGURES

Figure I
Schematic Diagram of the Trailer

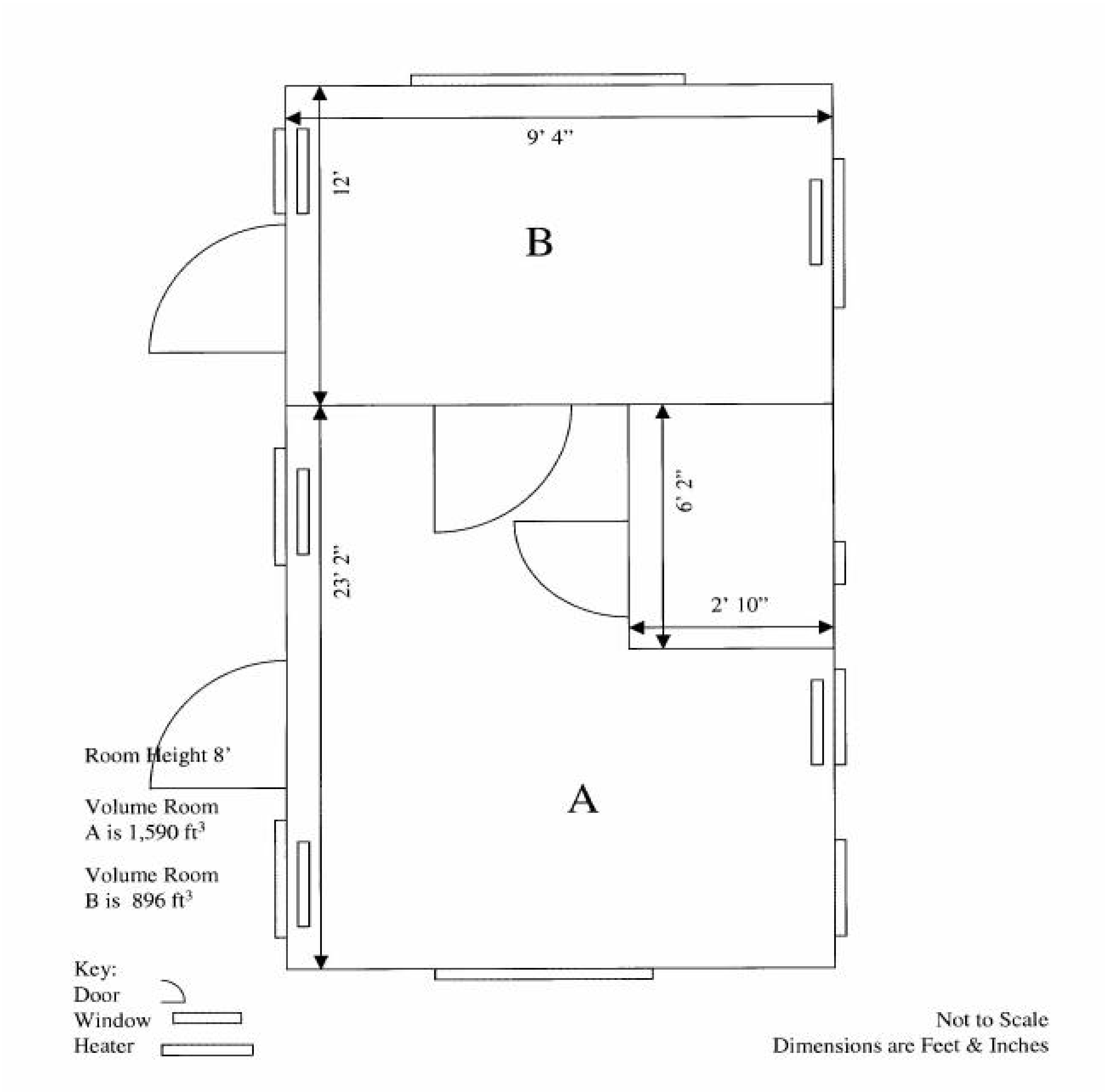
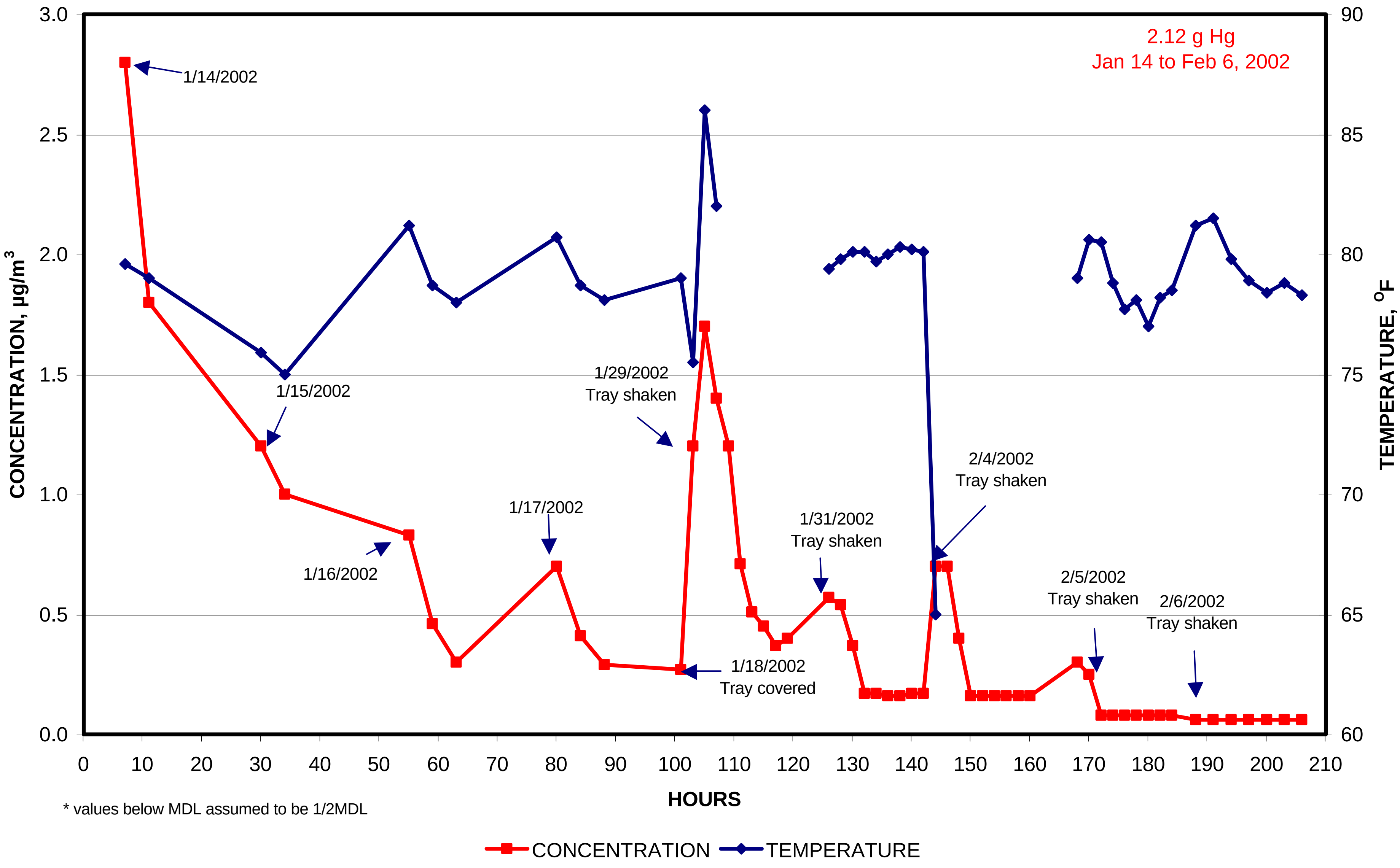


Figure 1
Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1
NIOSH RESULTS*



* values below MDL assumed to be 1/2MDL

Figure 2
Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1
NIOSH & TRACKER Results

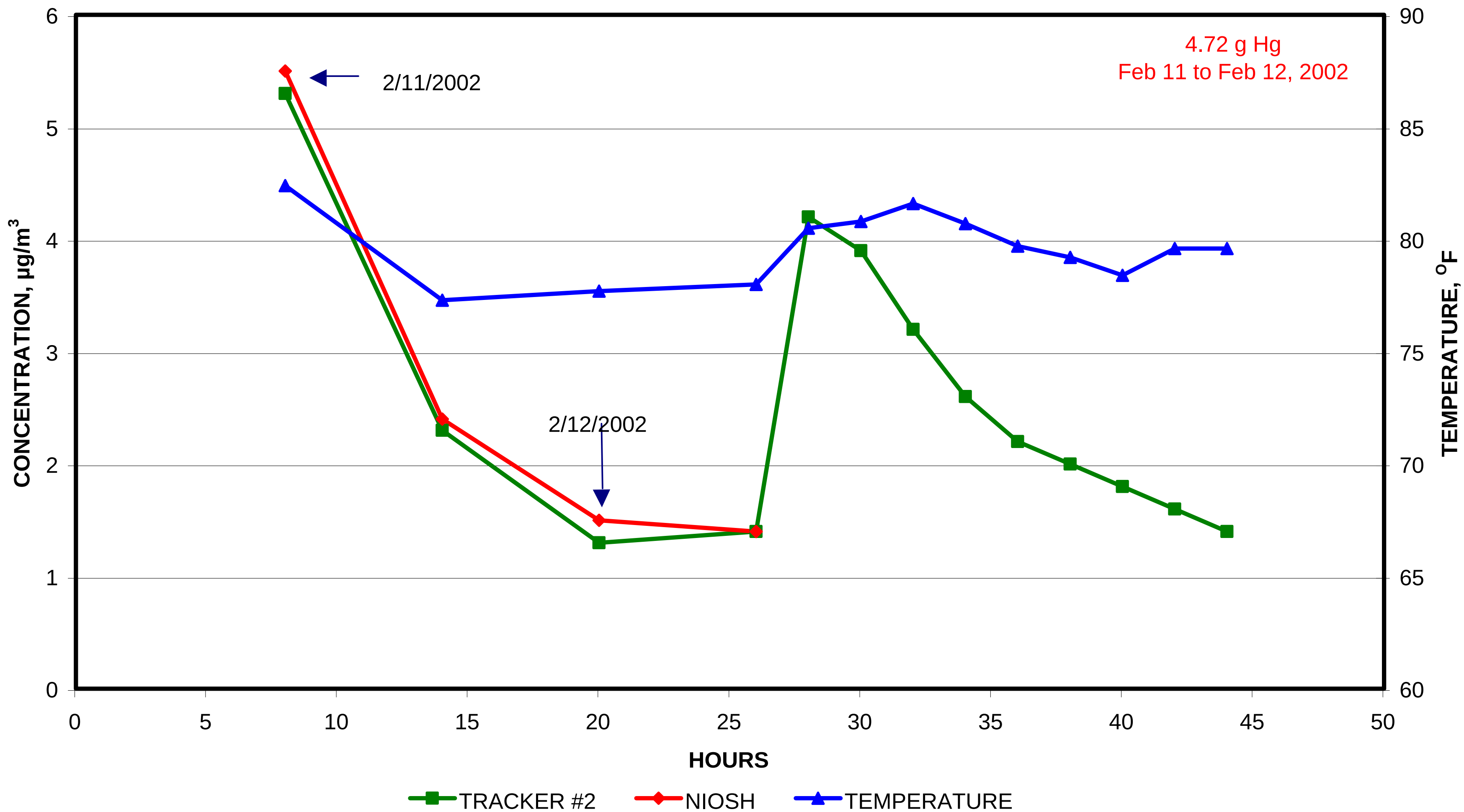


Figure 3
Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1
NIOSH & TRACKER Results

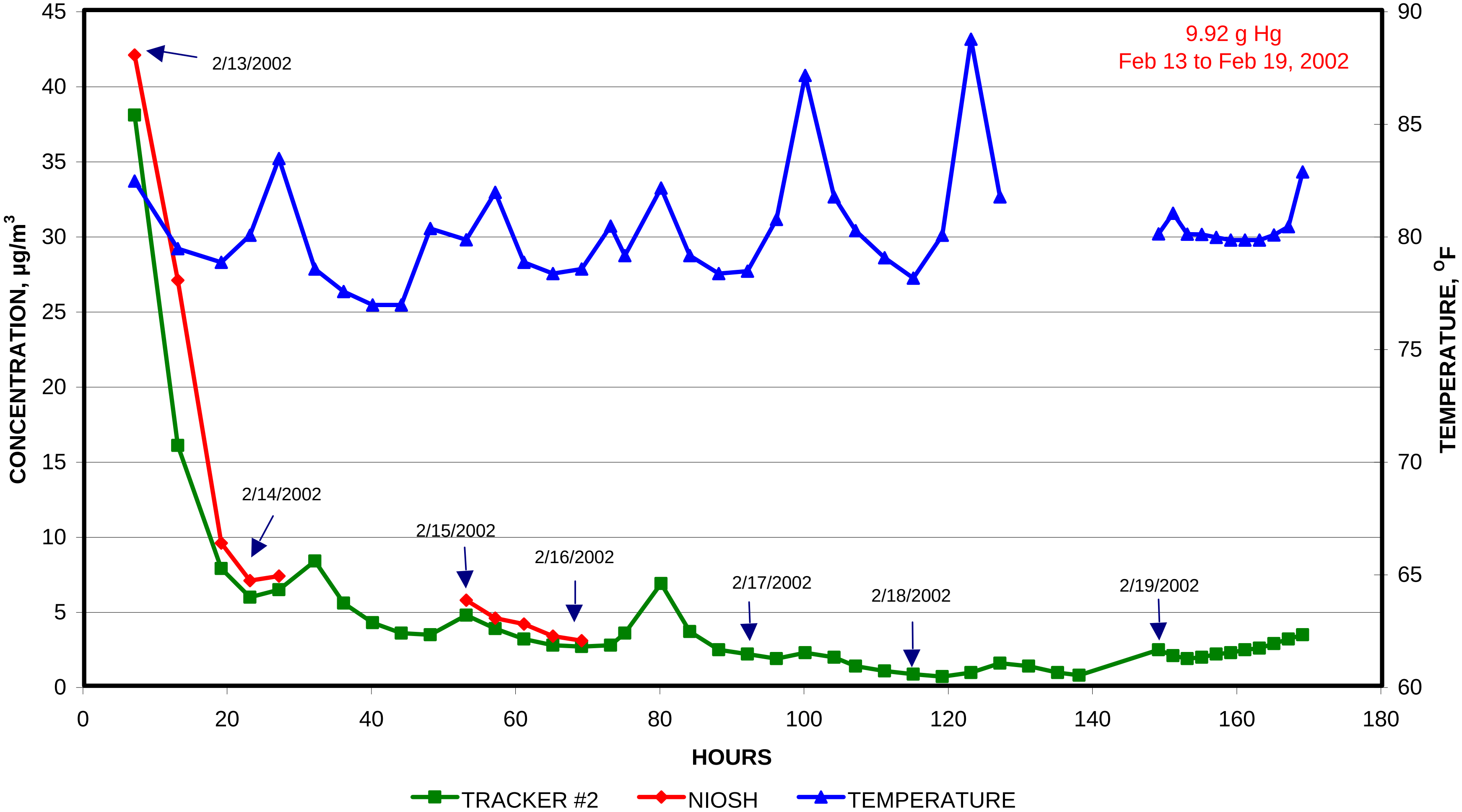


Figure 4
Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1
NIOSH & TRACKER Results

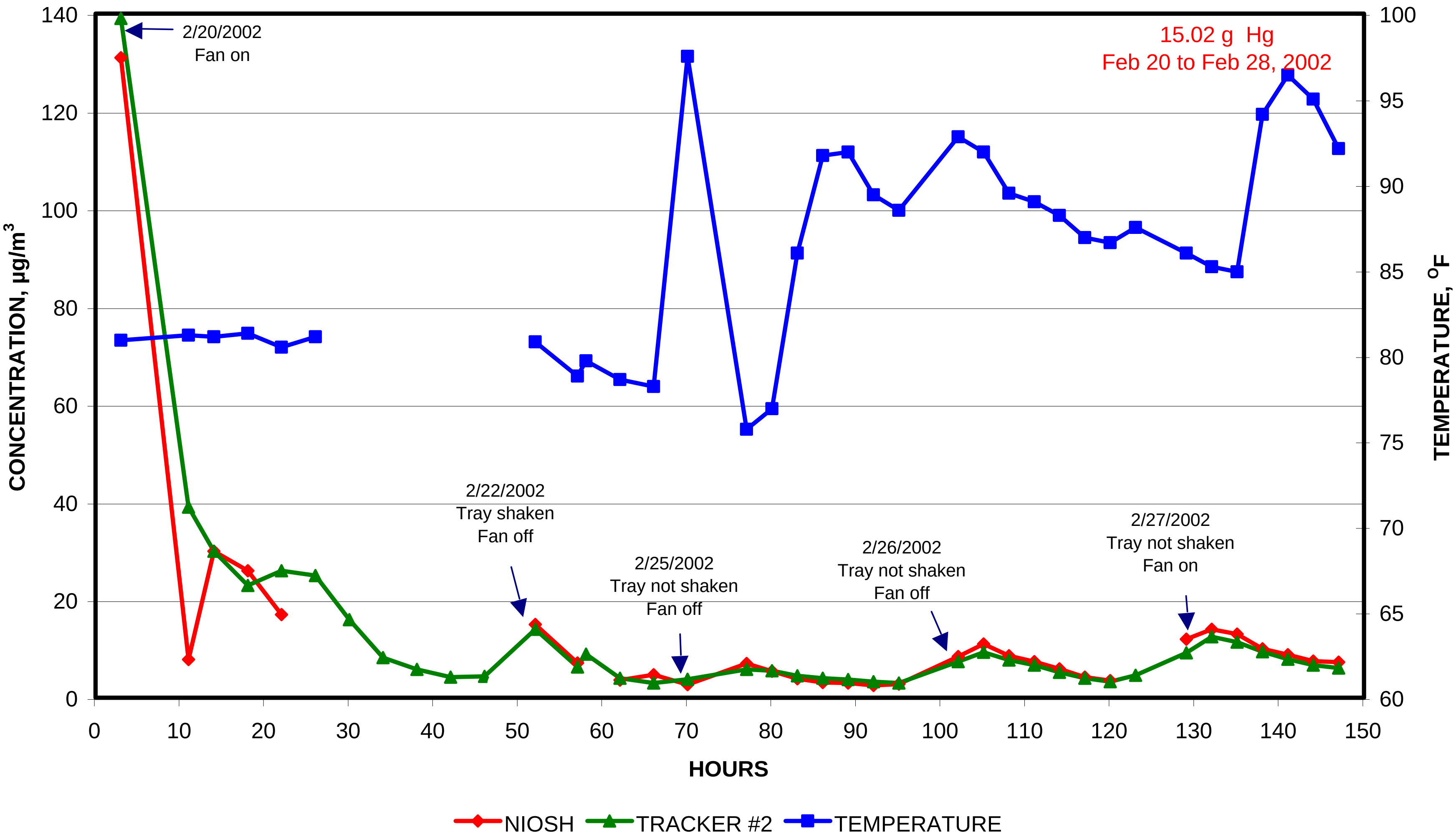


Figure 5
Simulation of Ritualistic Uses of Mercury in a Home: Experiment 2
NIOSH & TRACKER Results

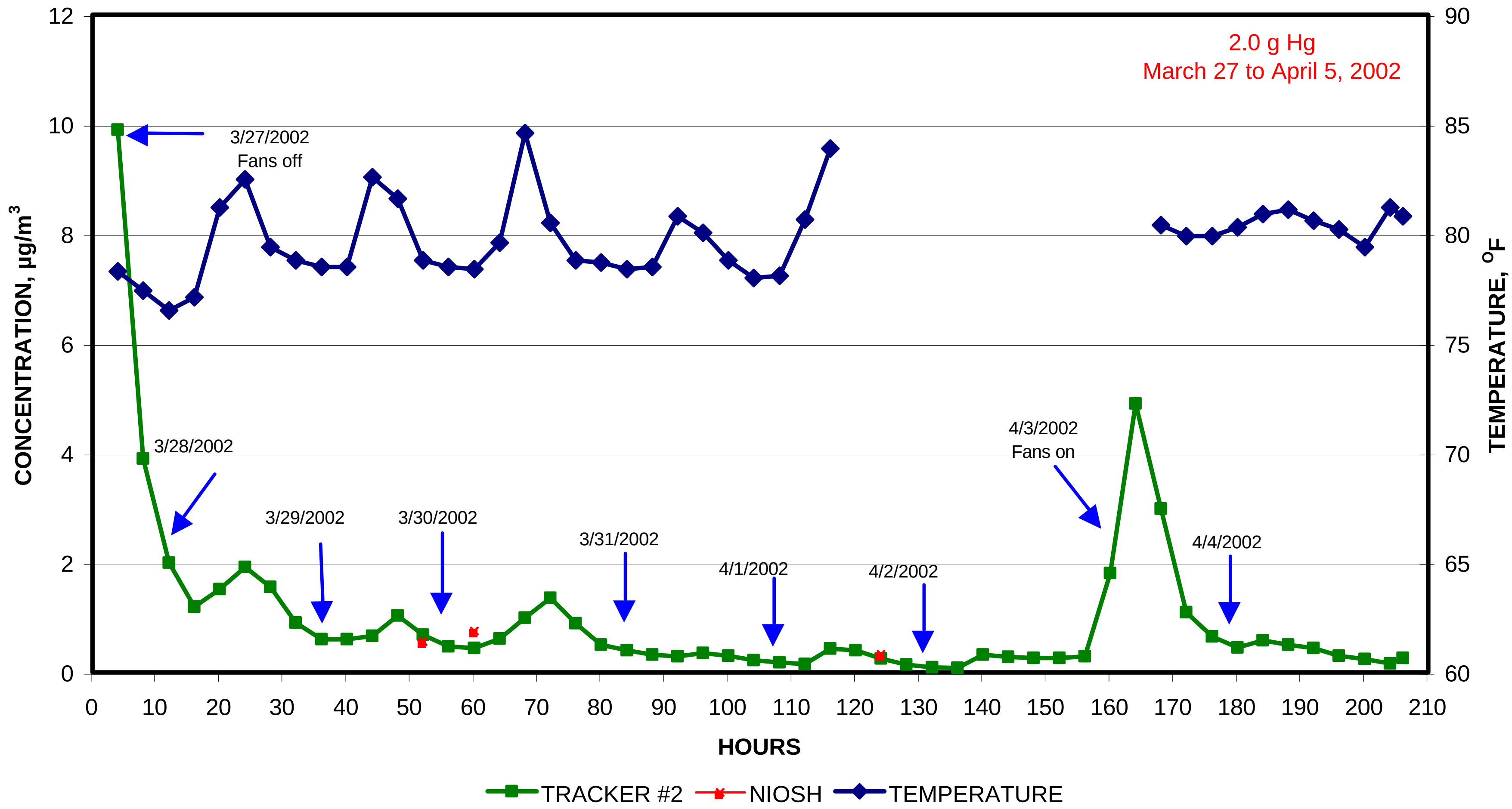


Figure 6
Broken Clinical Thermometer Simulation: Experiment 3
NIOSH & TRACKER Results

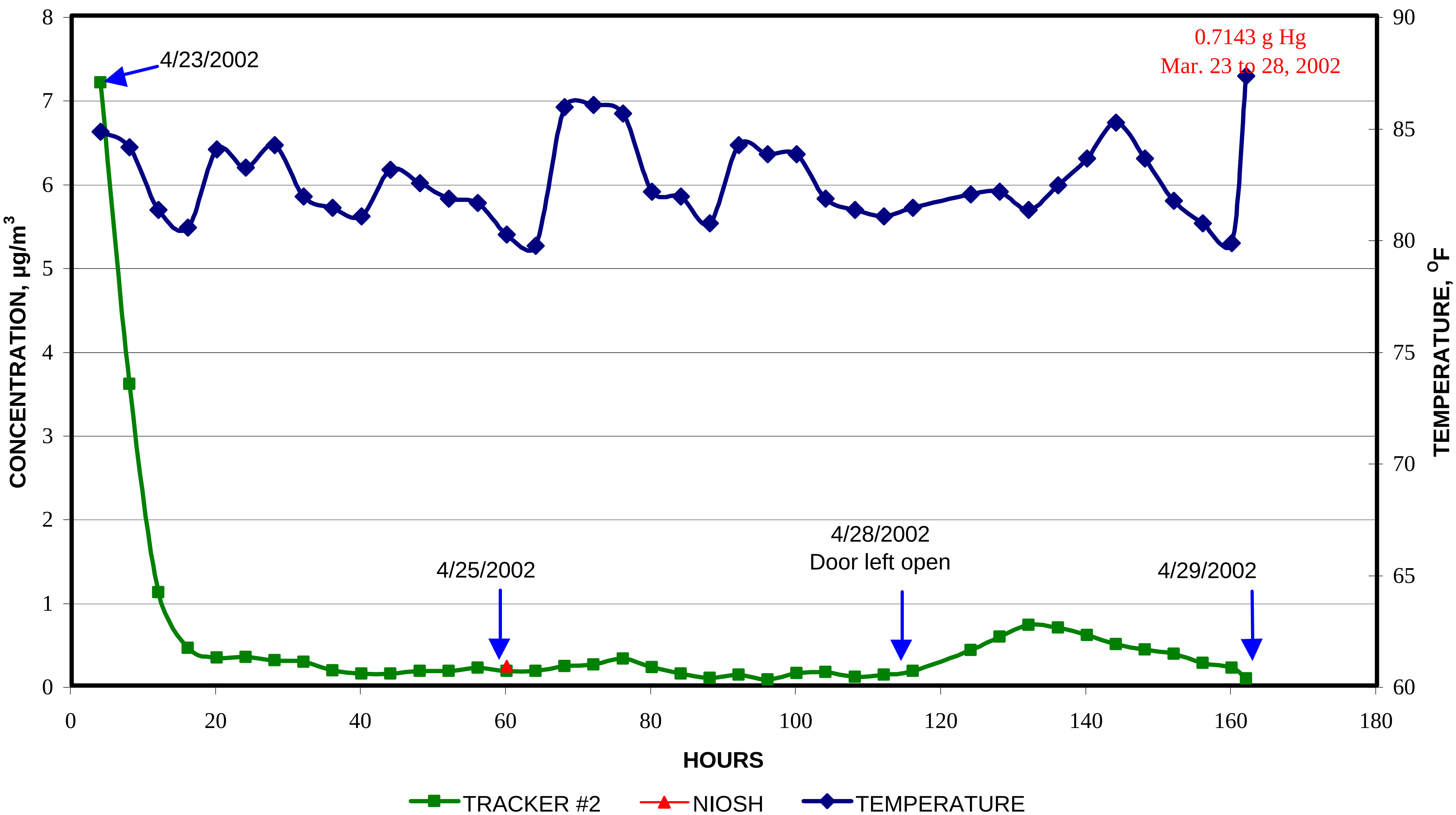


Figure 7
Effect of Surface Area Simulation: Experiment 4
TRACKER Results

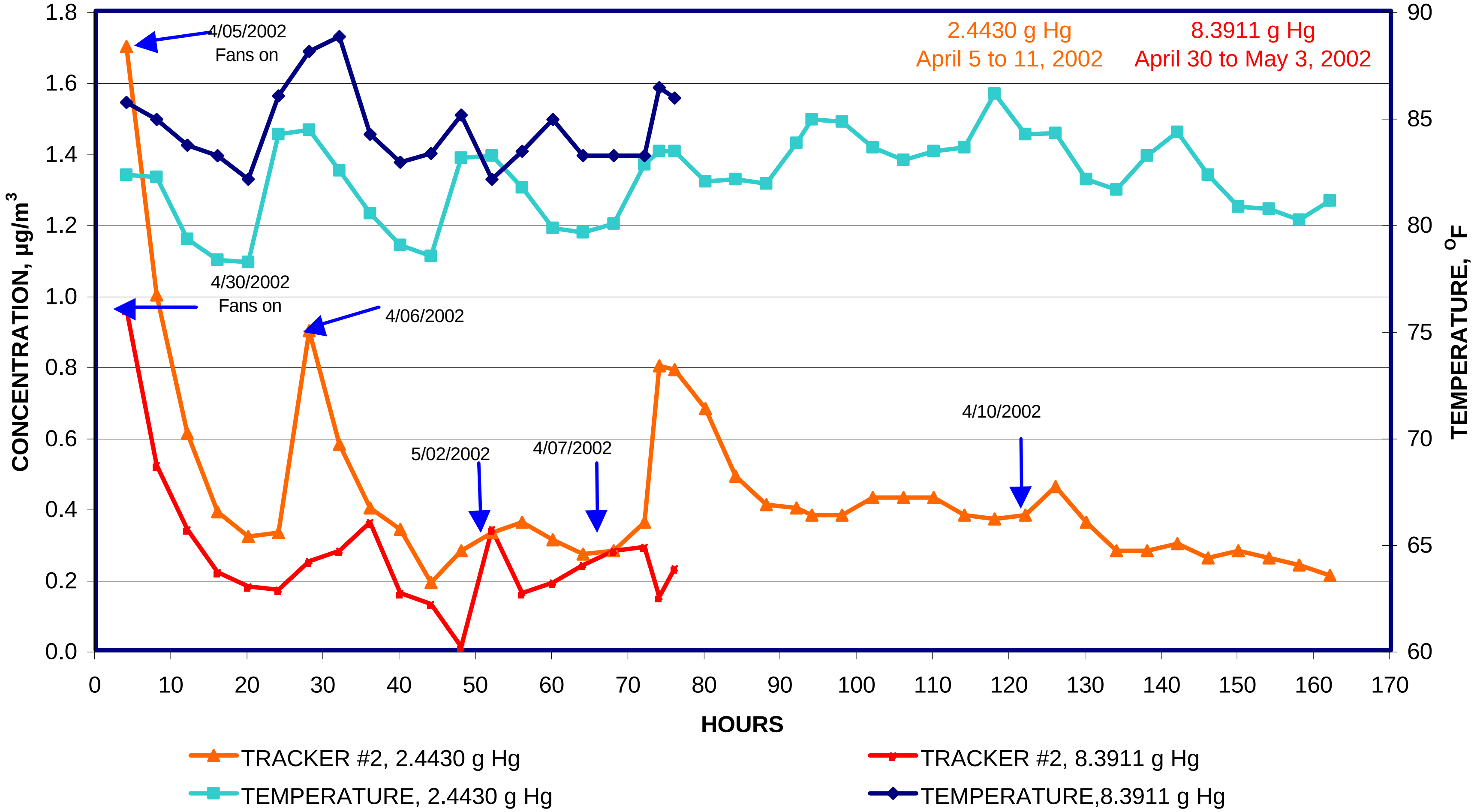


Figure 8
Effect of Surface Area Simulation: Experiment 5
TRACKER Results

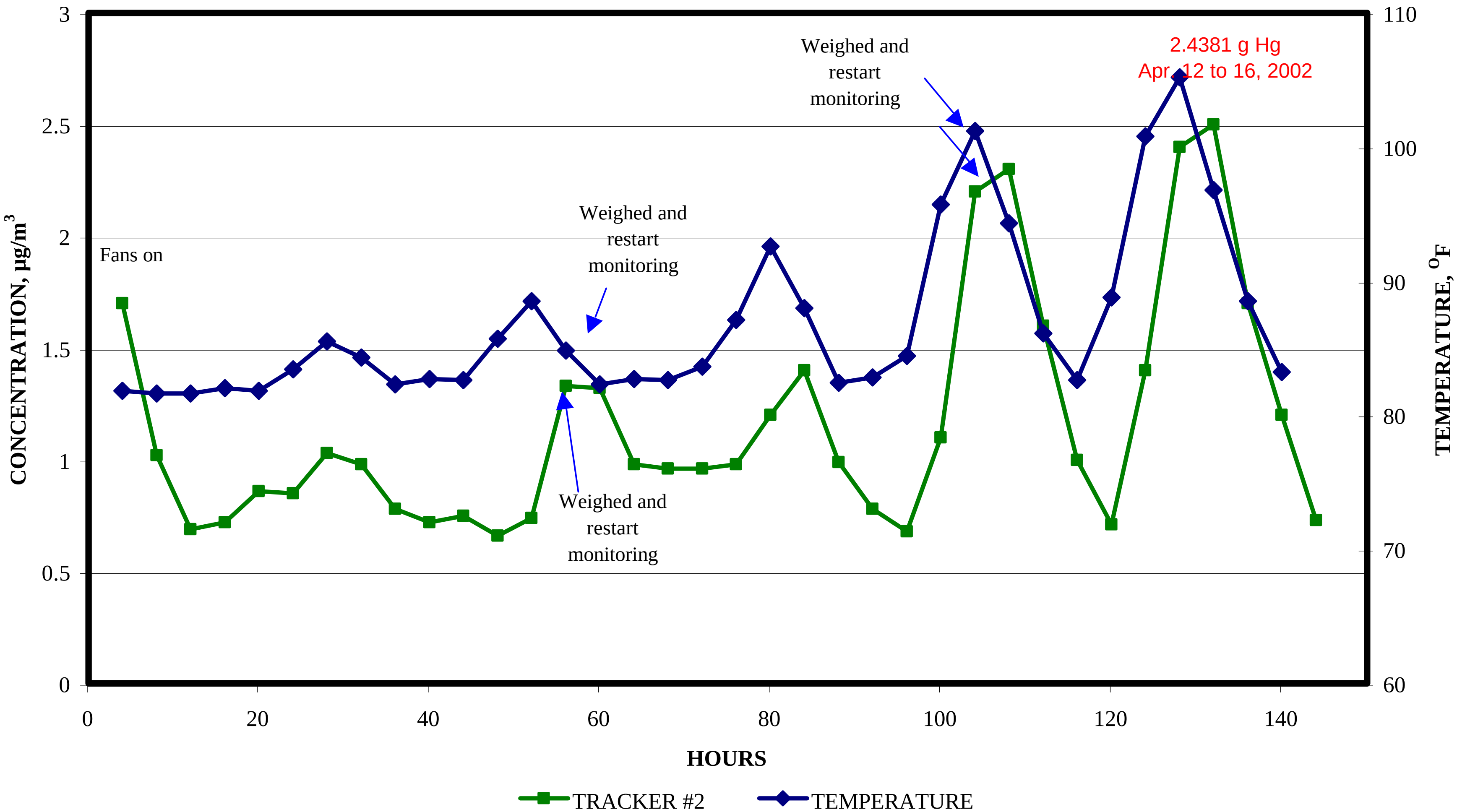


Figure 9
Effect of Surface Area Simulation: Experiment 5
TRACKER Results

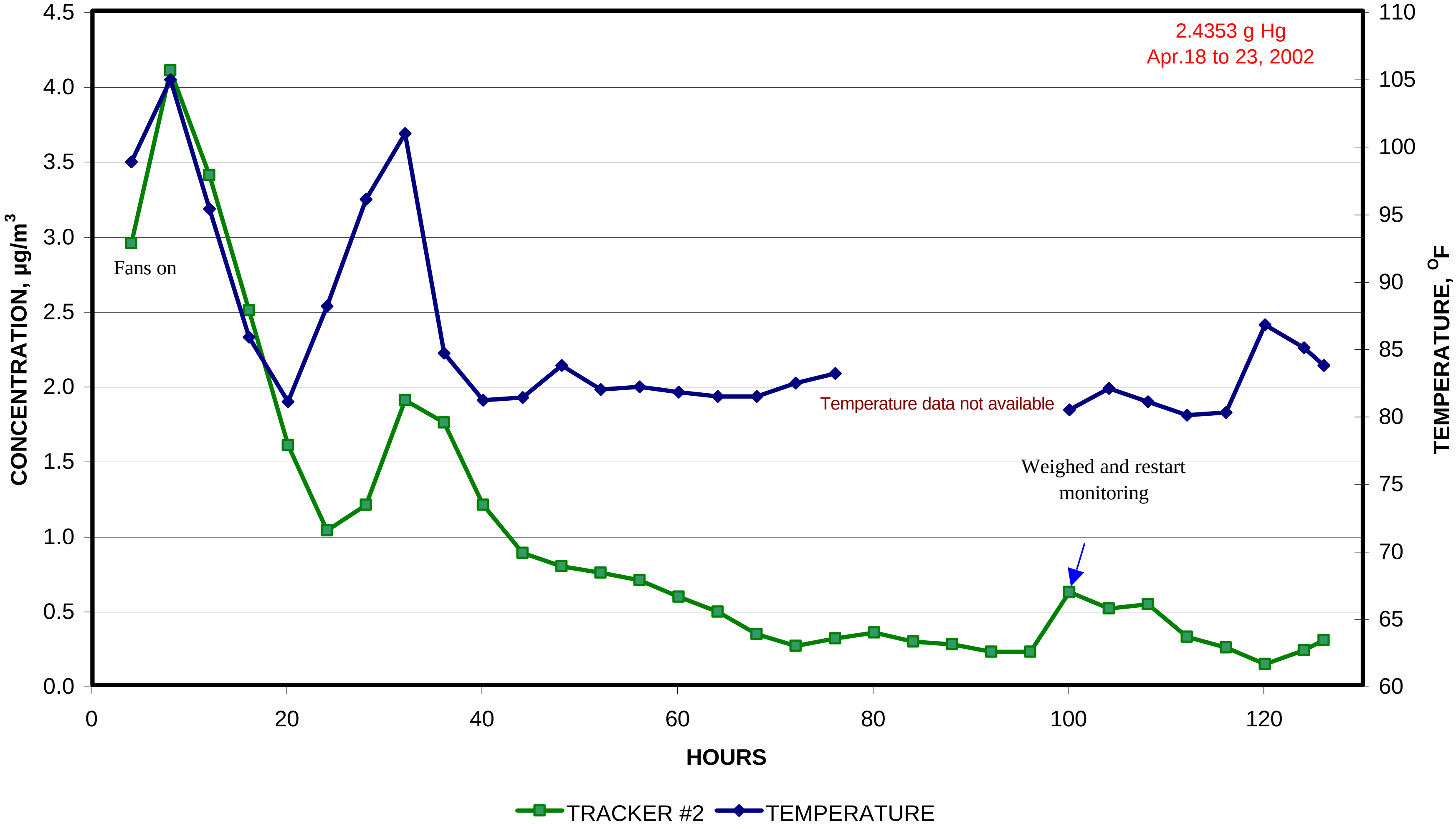


Figure 10
Effect of Surface Area Simulation: Experiment 5
TRACKER Results

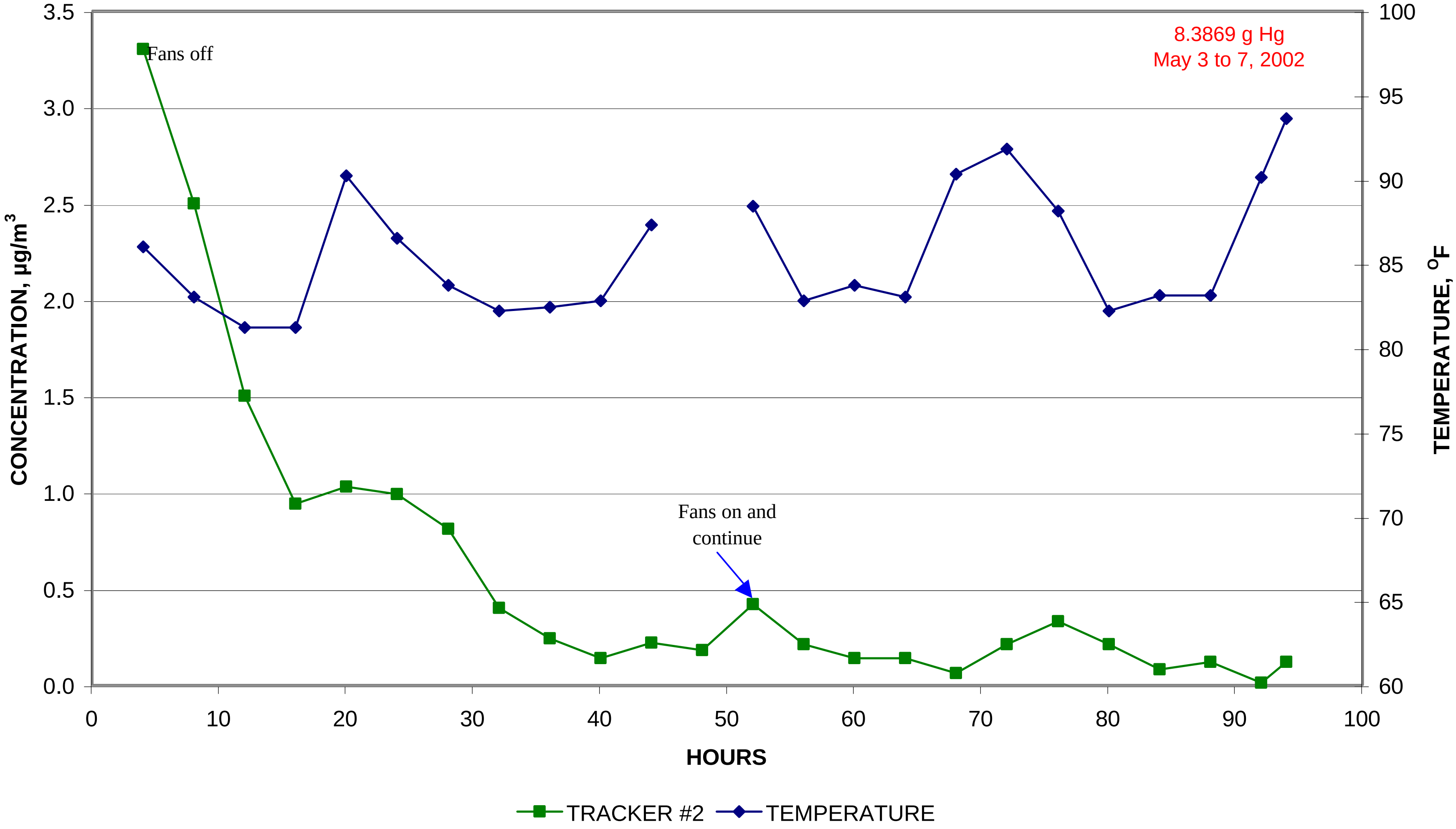


Figure 11
Effect of Surface Area Simulation: Experiment 5
LUMEX, TRACKER, & NIOSH Results

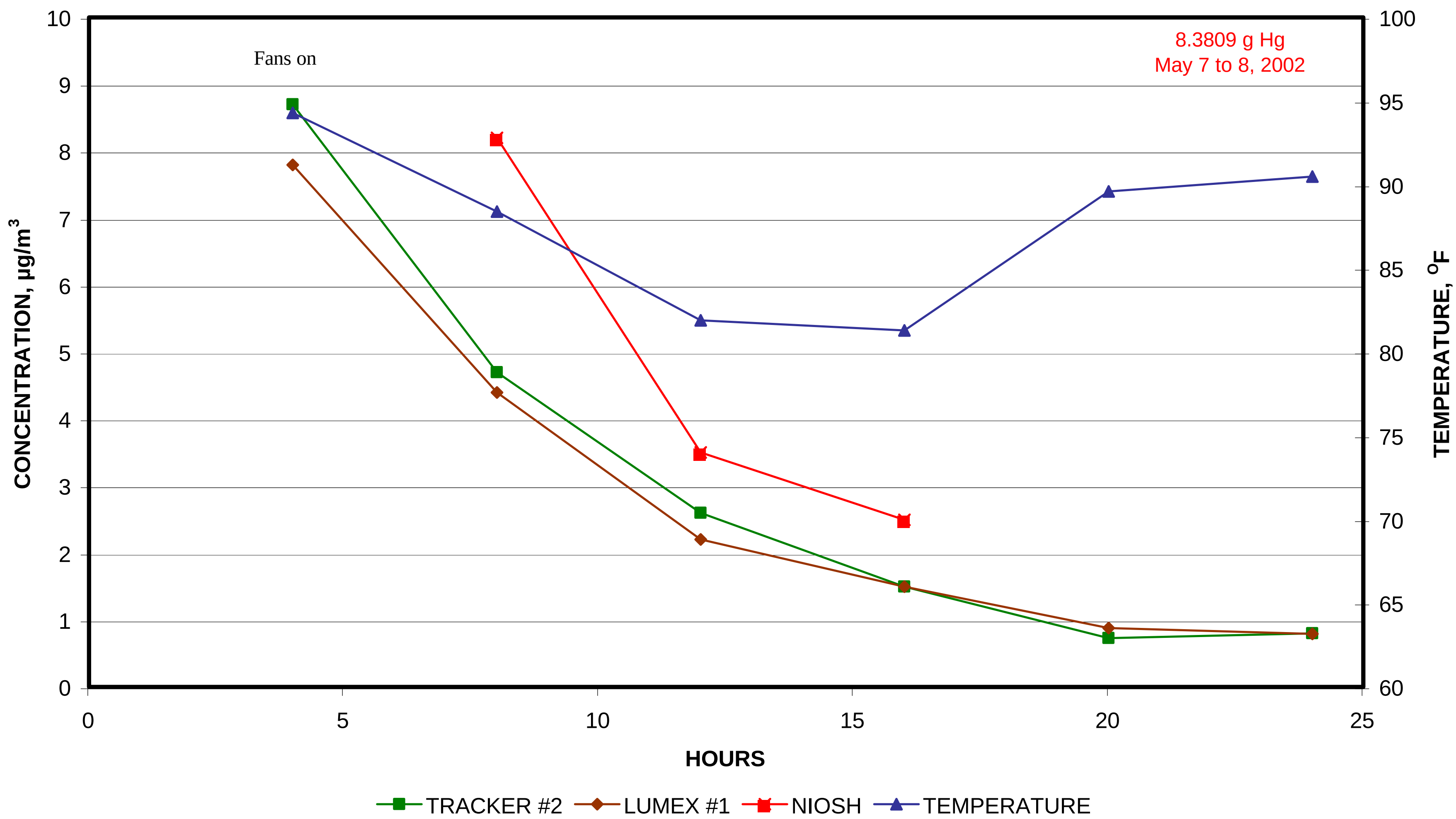


Figure 12
Surface Area Regeneration Simulation: Experiment 6
TRACKER, LUMEX & NIOSH Results

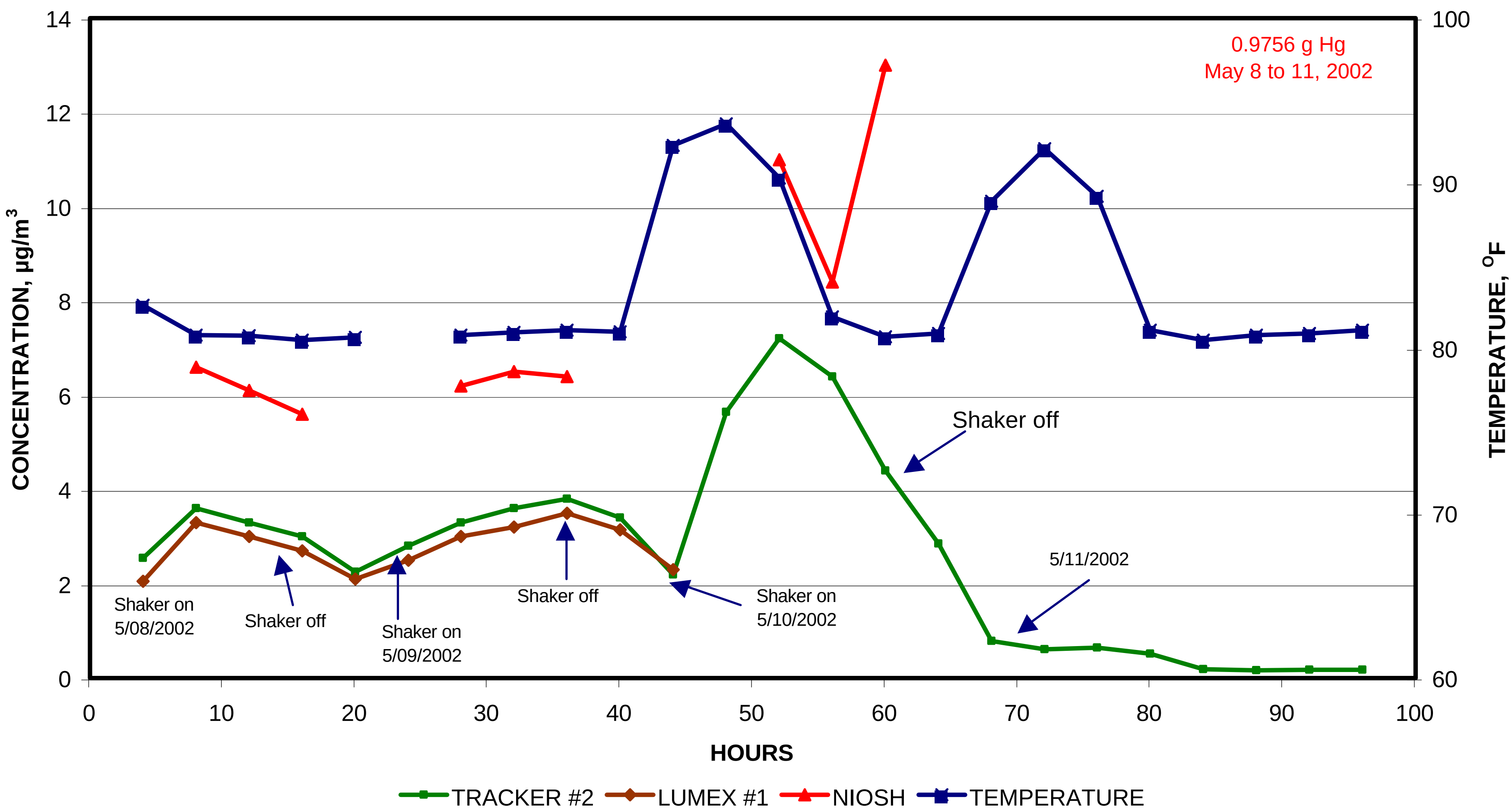


Figure 13
Surface Area Regeneration Simulation: Experiment 6
TRACKER, LUMEX & NIOSH Results

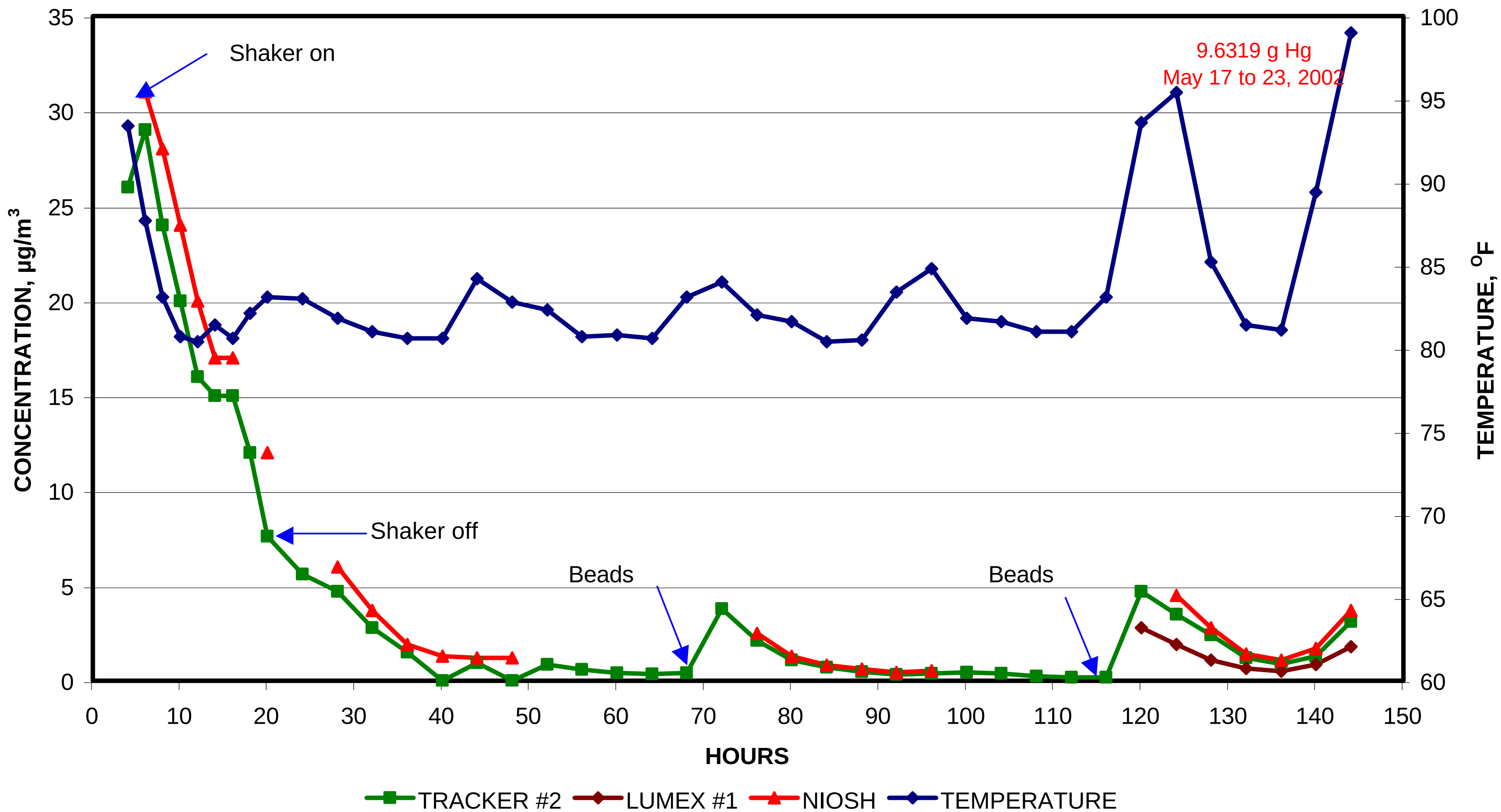


Figure 14
Simulation of Ritualistic Mercury Use in a Large Home Room: Experiment 7
TRACKER, LUMEX & NIOSH Results

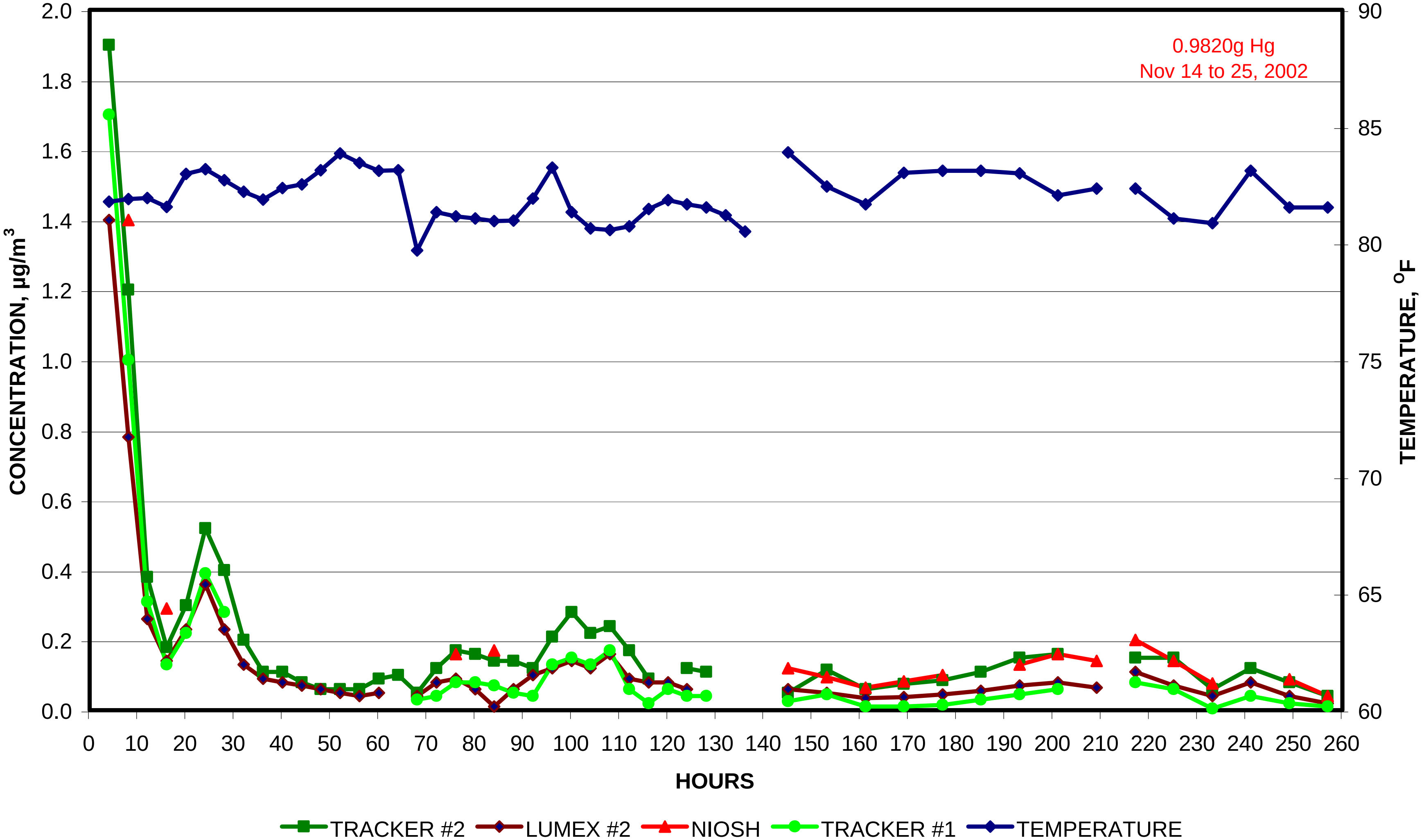


Figure 15
Simulation of Ritualistic Mercury Use in a Large Home Room: Experiment 7
TRACKER, LUMEX & NIOSH Results

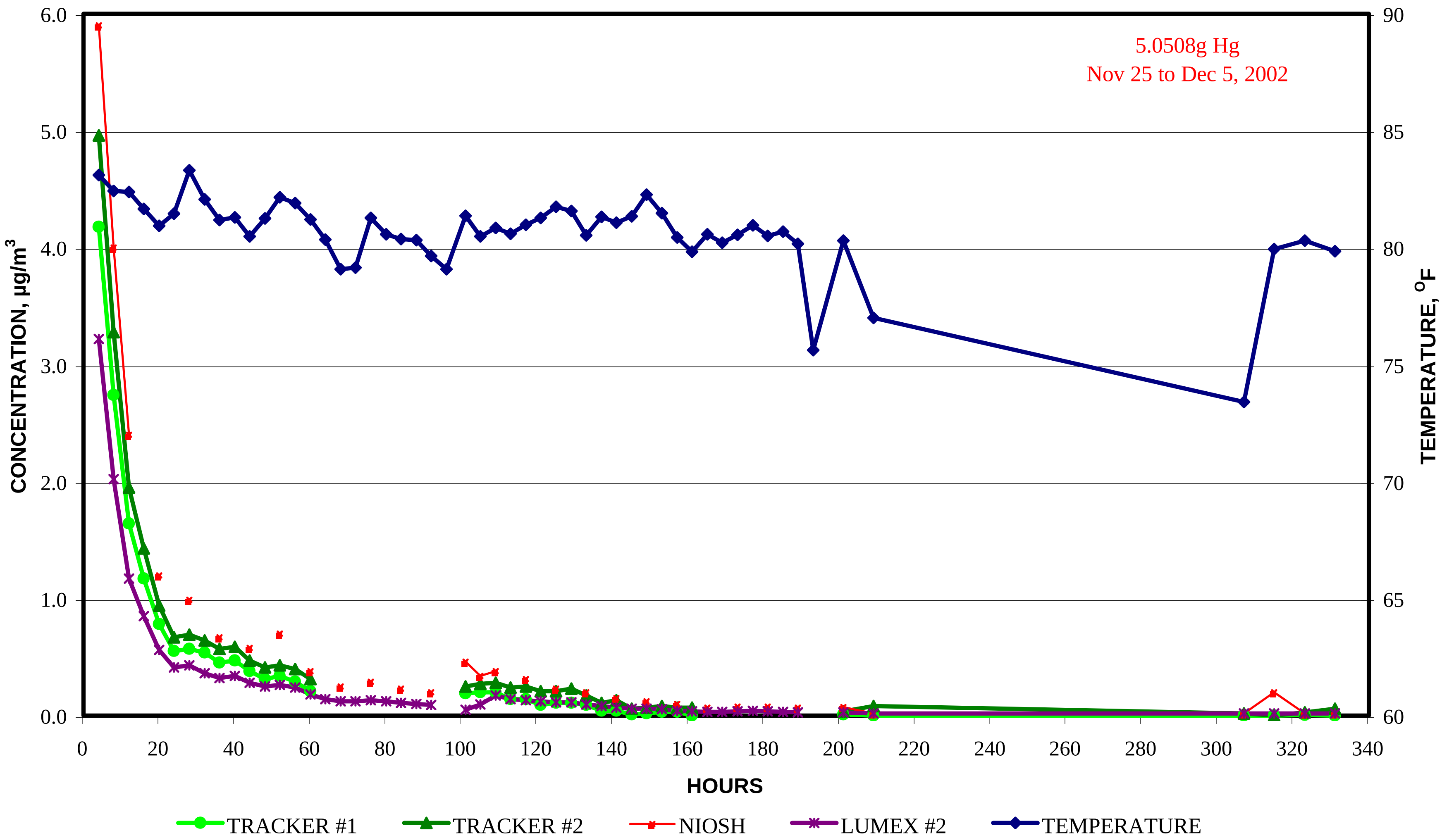


Figure 16
Simulation of Ritualistic Mercury Use of in a Large Home Room: Experiment 7
TRACKER, LUMEX & NIOSH Results

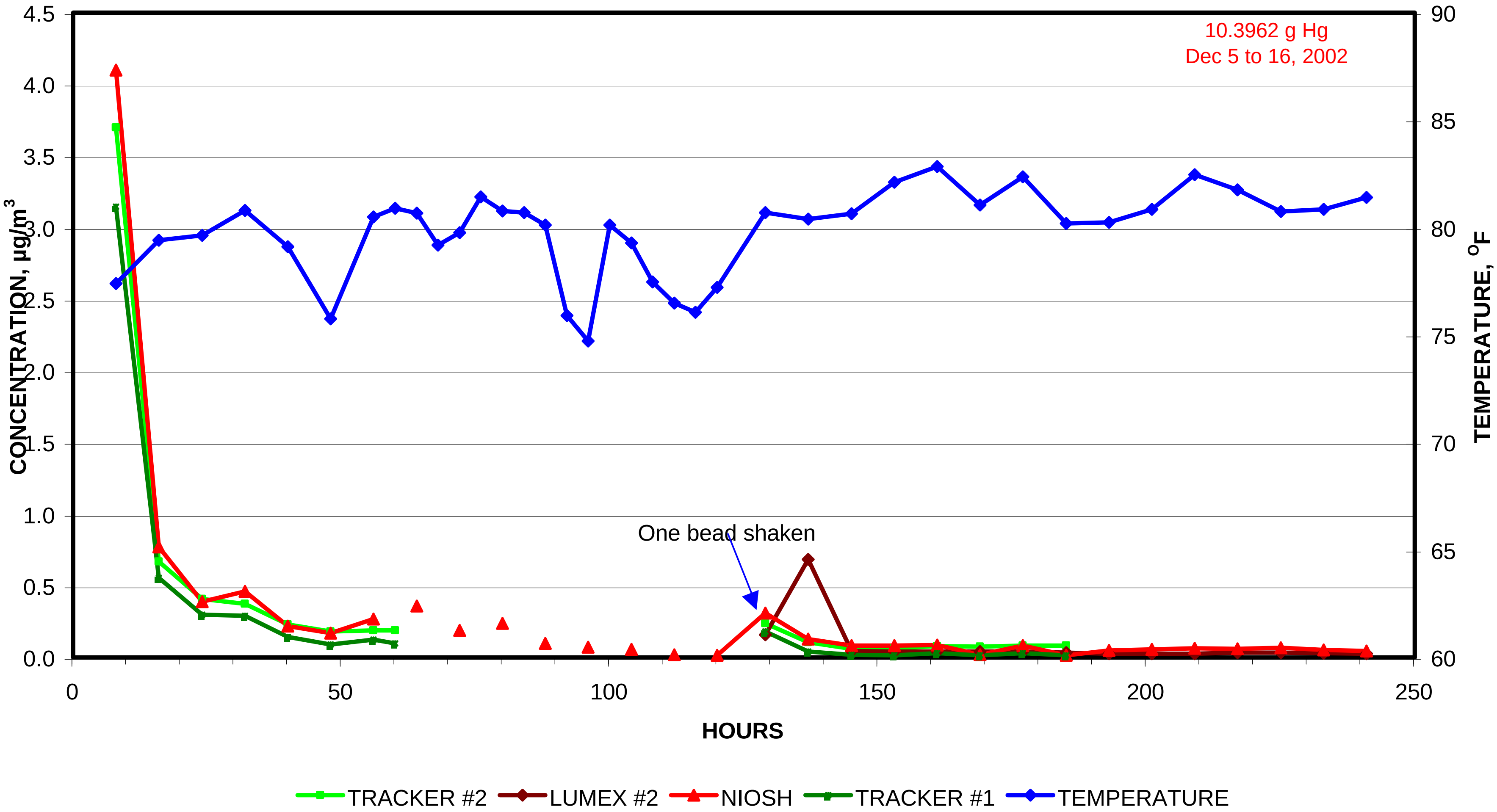


Figure 17
Mercury Vapor Emission Rate: Experiment 8
TRACKER Results

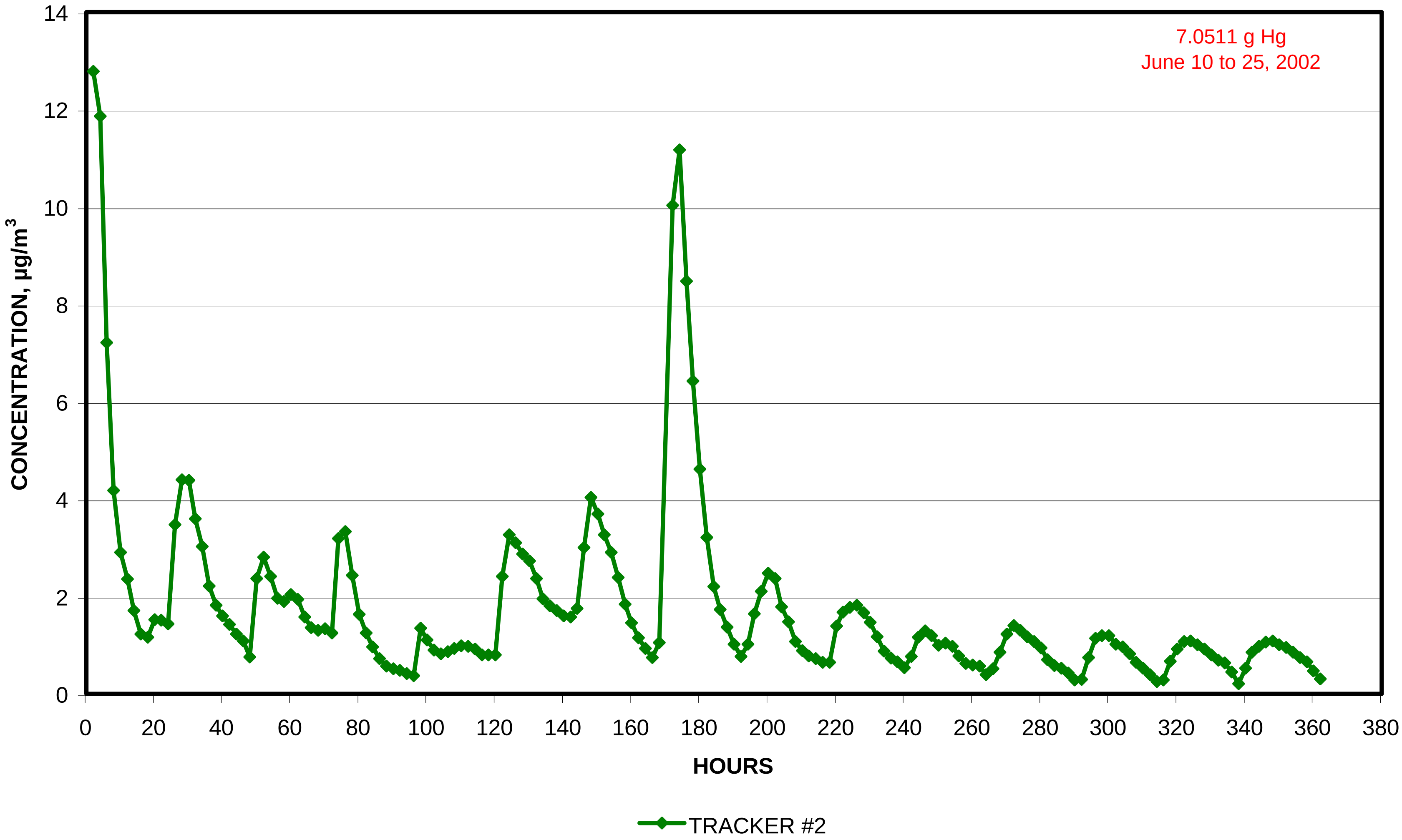


Figure 18
Mercury Vapor Emission Rate: Experiment 8
TRACKER Results

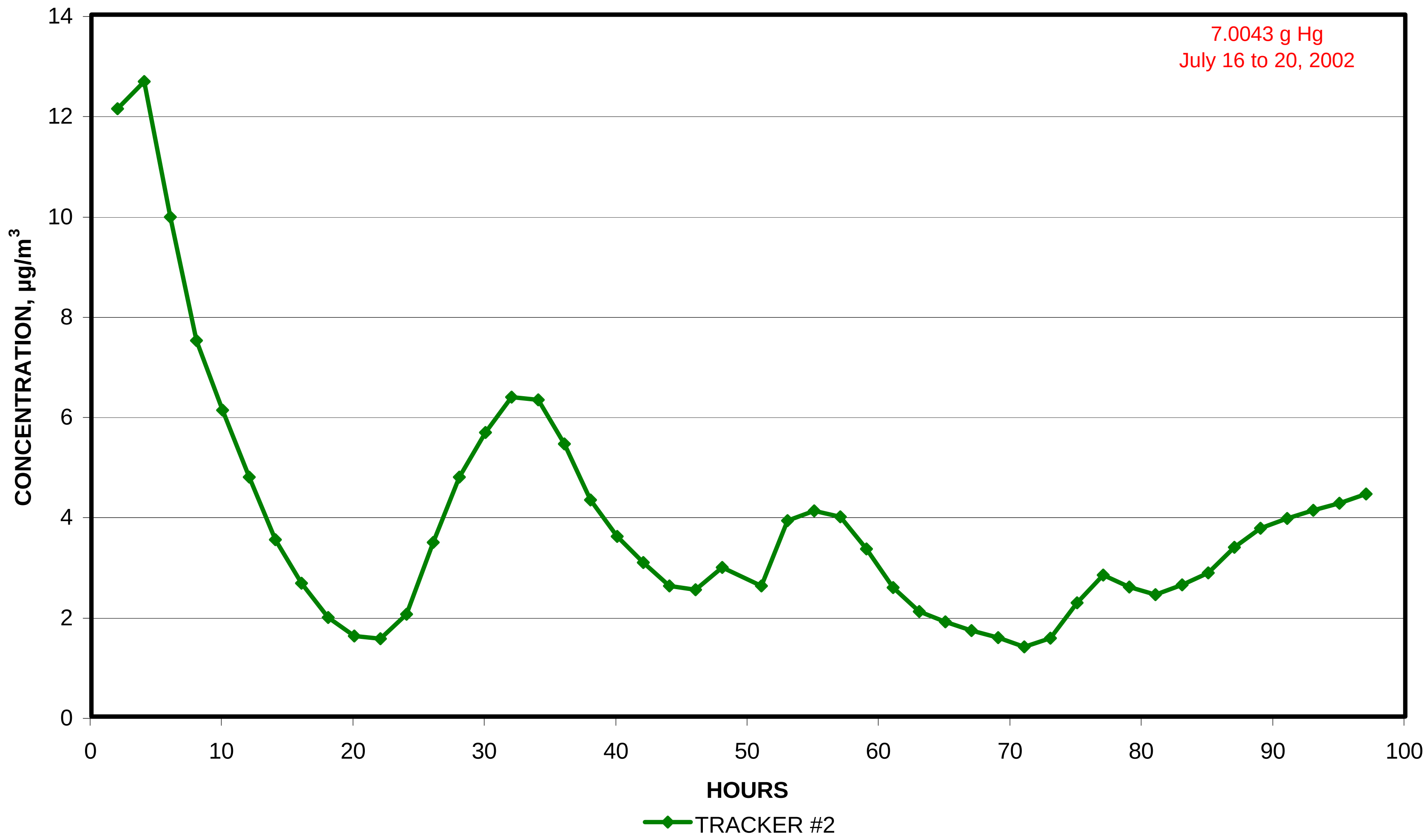


Figure 19
Mercury Vapor Emission Rate: Experiment 8
TRACKER & NIOSH Results

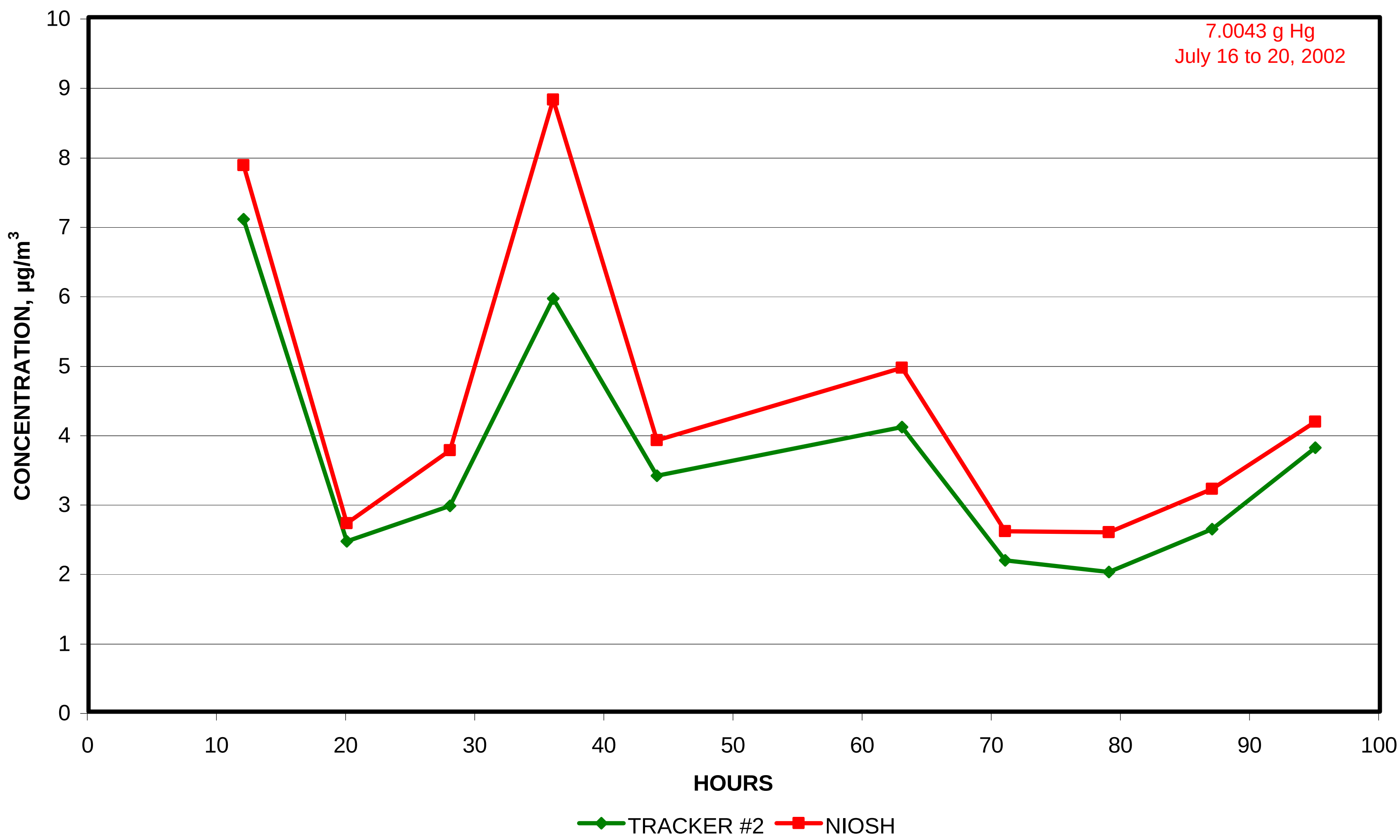


Figure 20
Mercury Vapor Emission Rate: Experiment 8
TRACKER Results

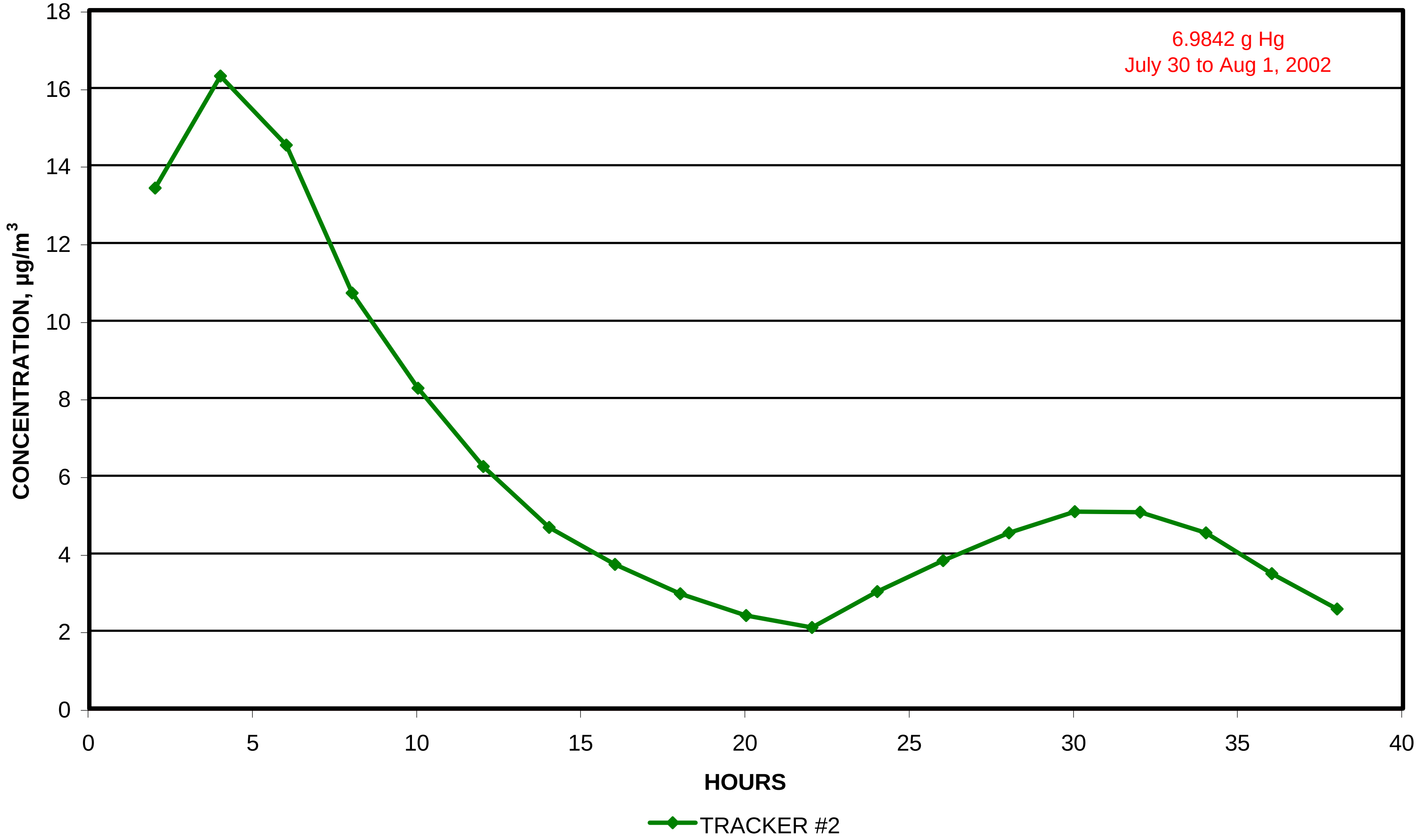


Figure 21
Mercury Vapor Emission Rate: Experiment 8
TRACKER & NIOSH Results

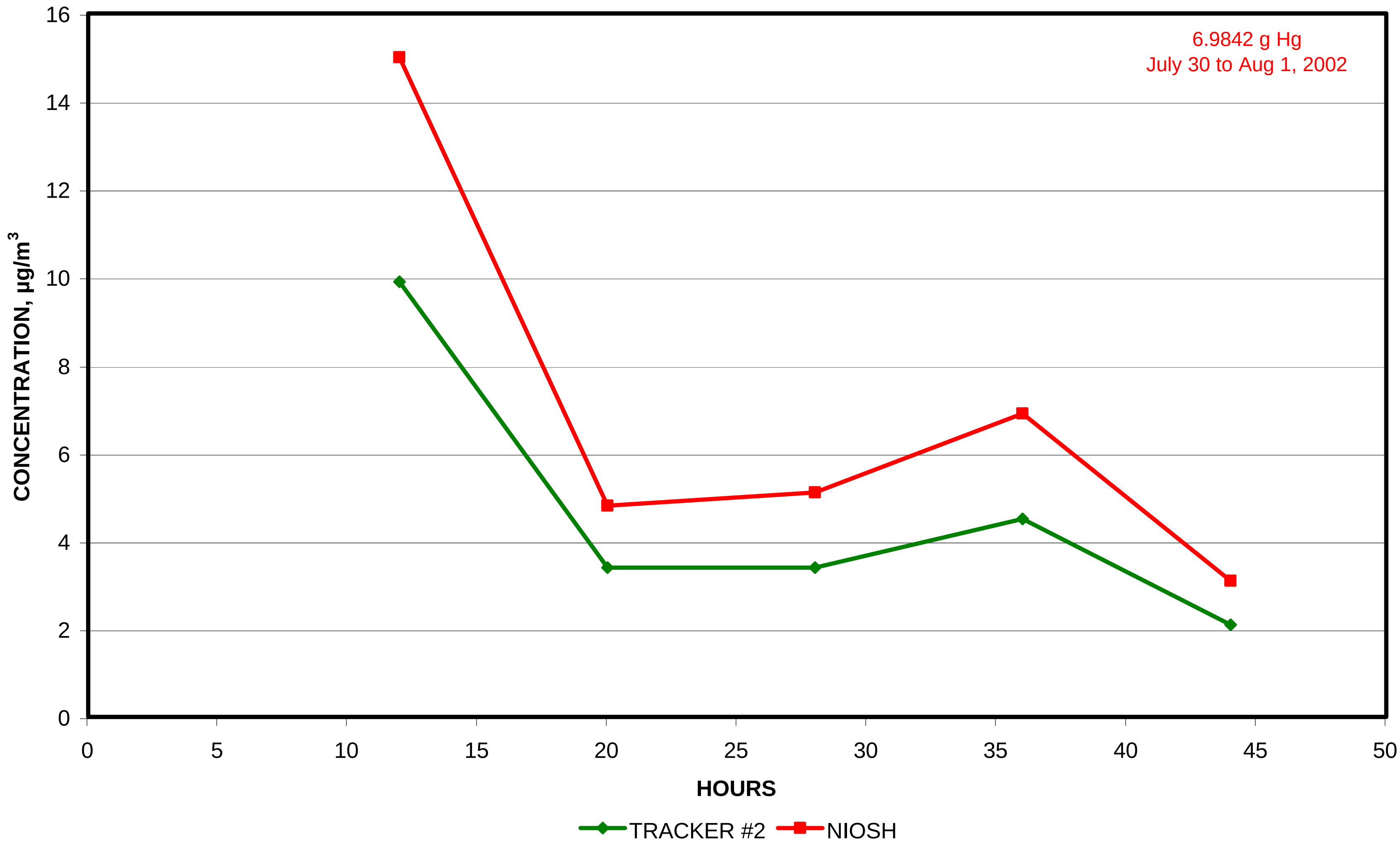


Figure 22
Mercury Vapor Emission: Experiment 8
TRACKER & LUMEX Results

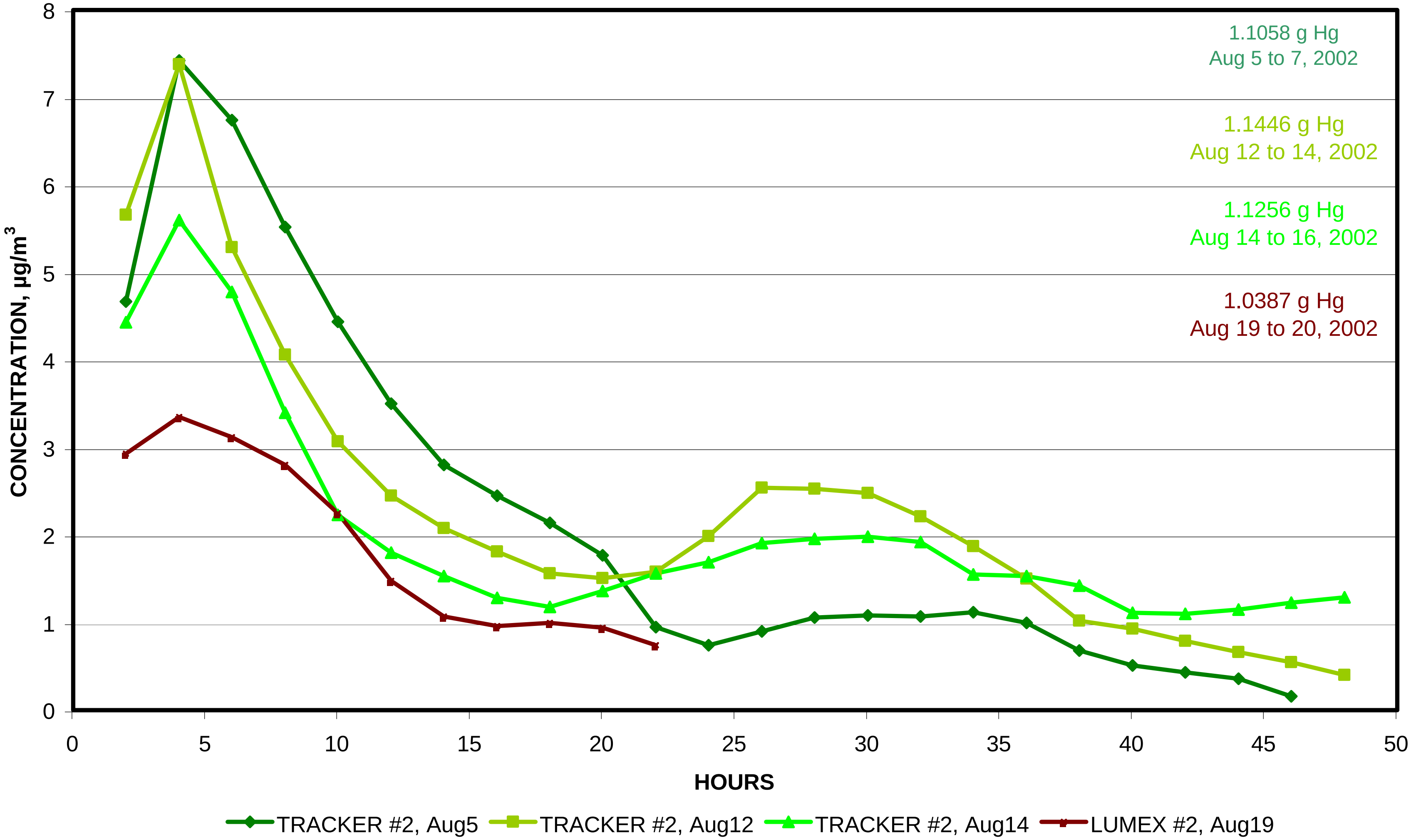
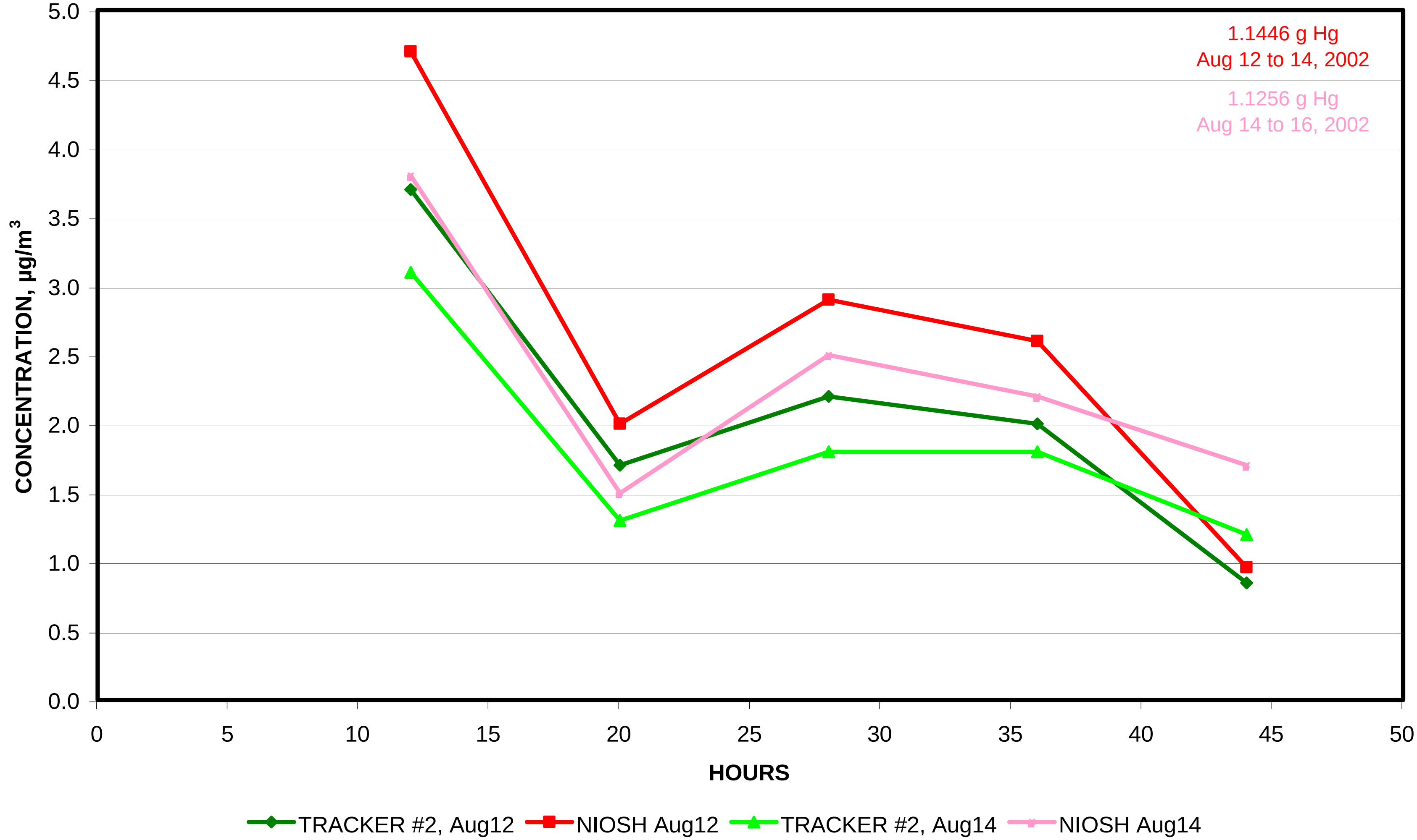


Figure 23
Mercury Vapor Emission Rate: Experiment 8
TRACKER & NIOSH Results



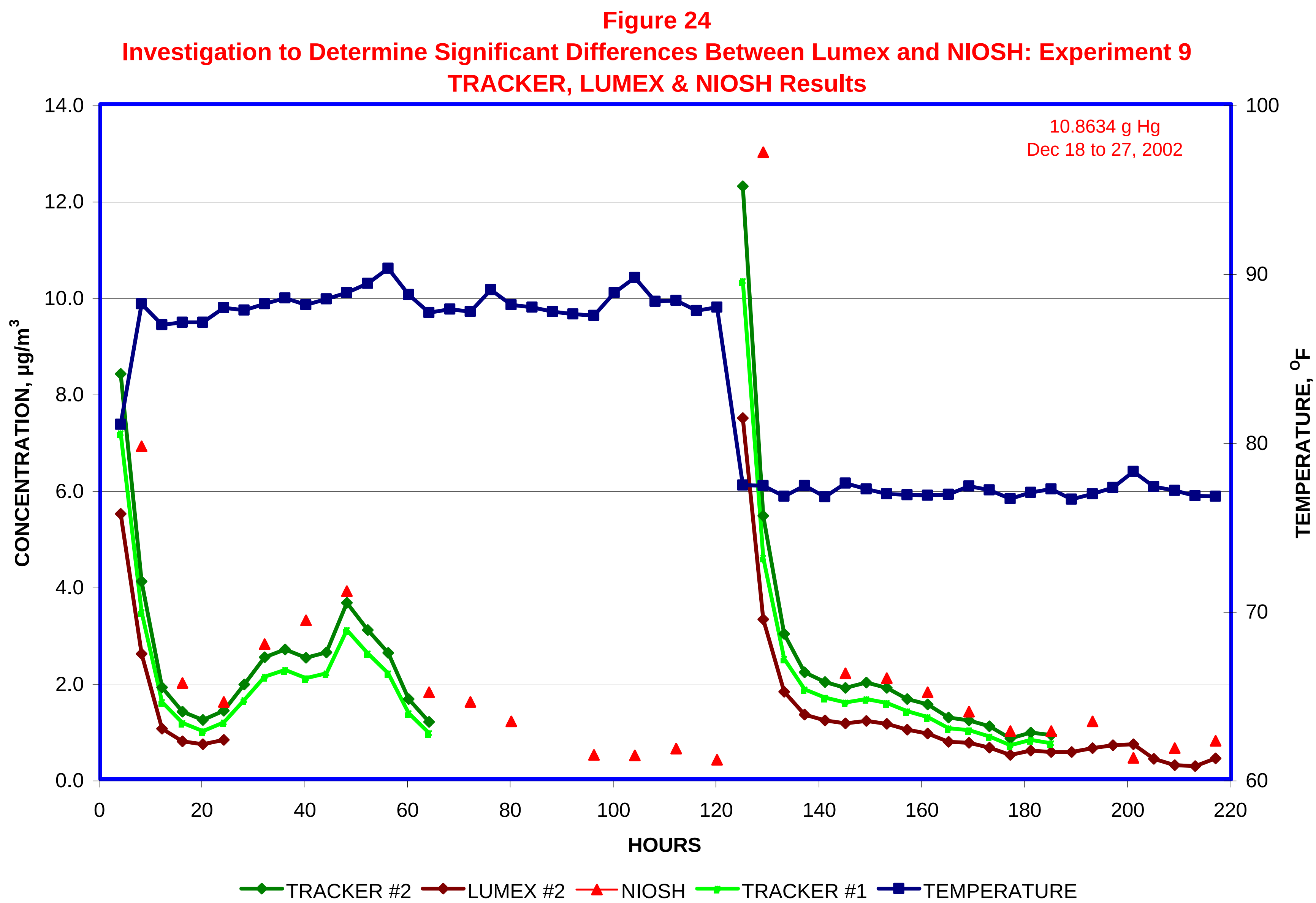


Figure 24
Investigation to Determine Significant Differences Between Lumex and NIOSH: Experiment 9
TRACKER, LUMEX & NIOSH Results
10.8634 g Hg
Dec 18 to 27, 2002
CONCENTRATION, µg/m3
TEMPERATURE, oF
HOURS
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
100
90
80
70
60
0
20
40
60
80
100
120
140
160
180
200
220
TRACKER #2
LUMEX #2
NIOSH
TRACKER #1
TEMPERATURE

Figure 25
Setup for Calibrating Real Time Mercury Monitoring Instruments

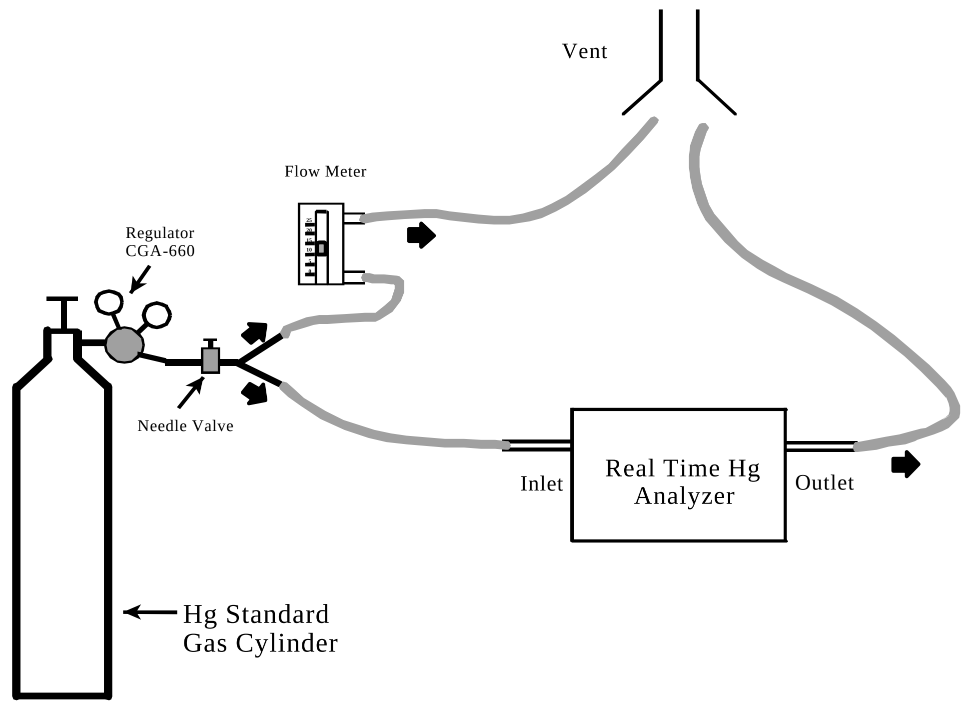


Figure 26
IInvestigation to Determine Significant Differences Between Lumex and NIOSH: Experiment 10
TRACKER, LUMEX & NIOSH Results

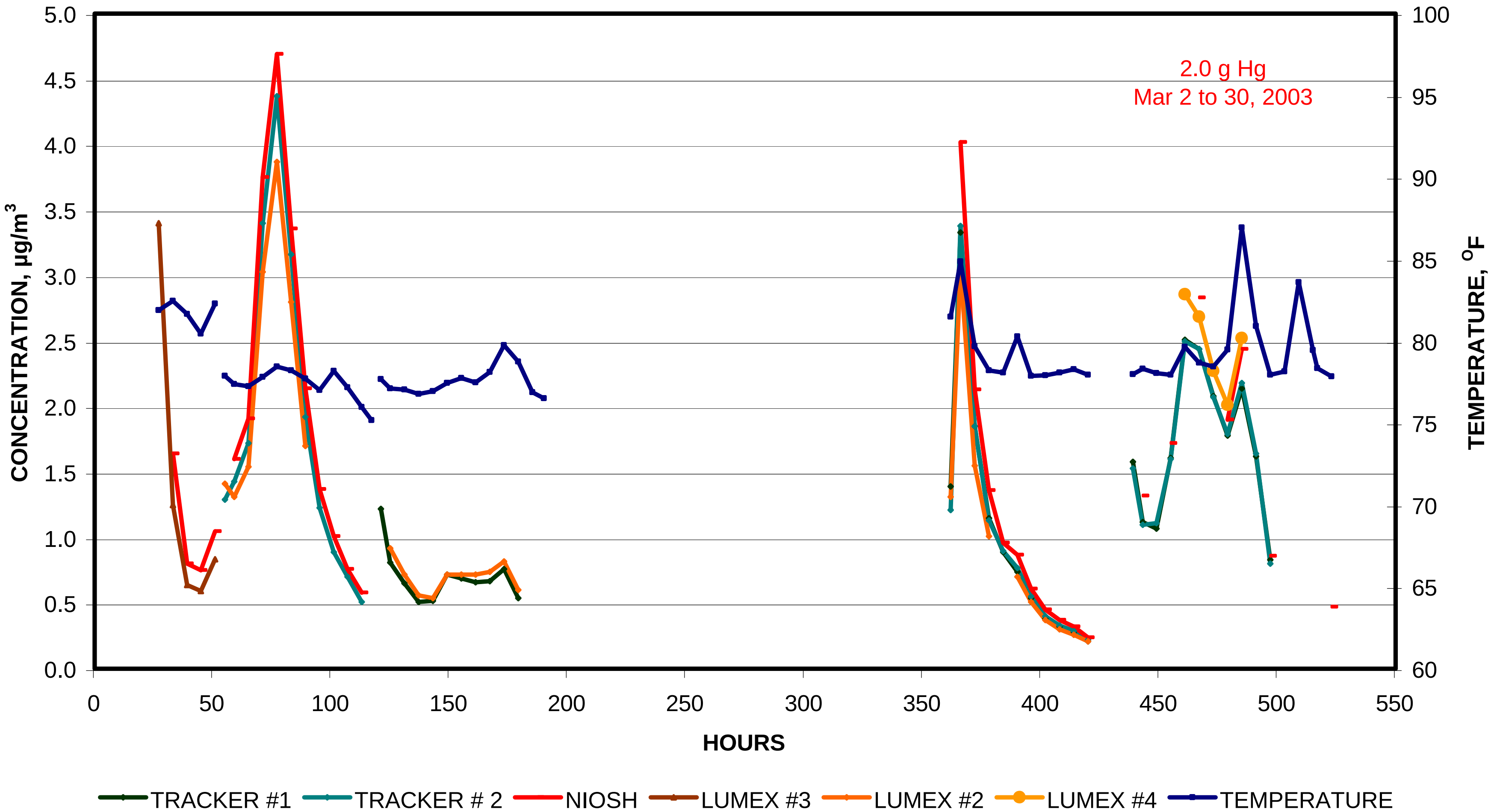


Figure 27
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Lumex Results - 08/05/2002

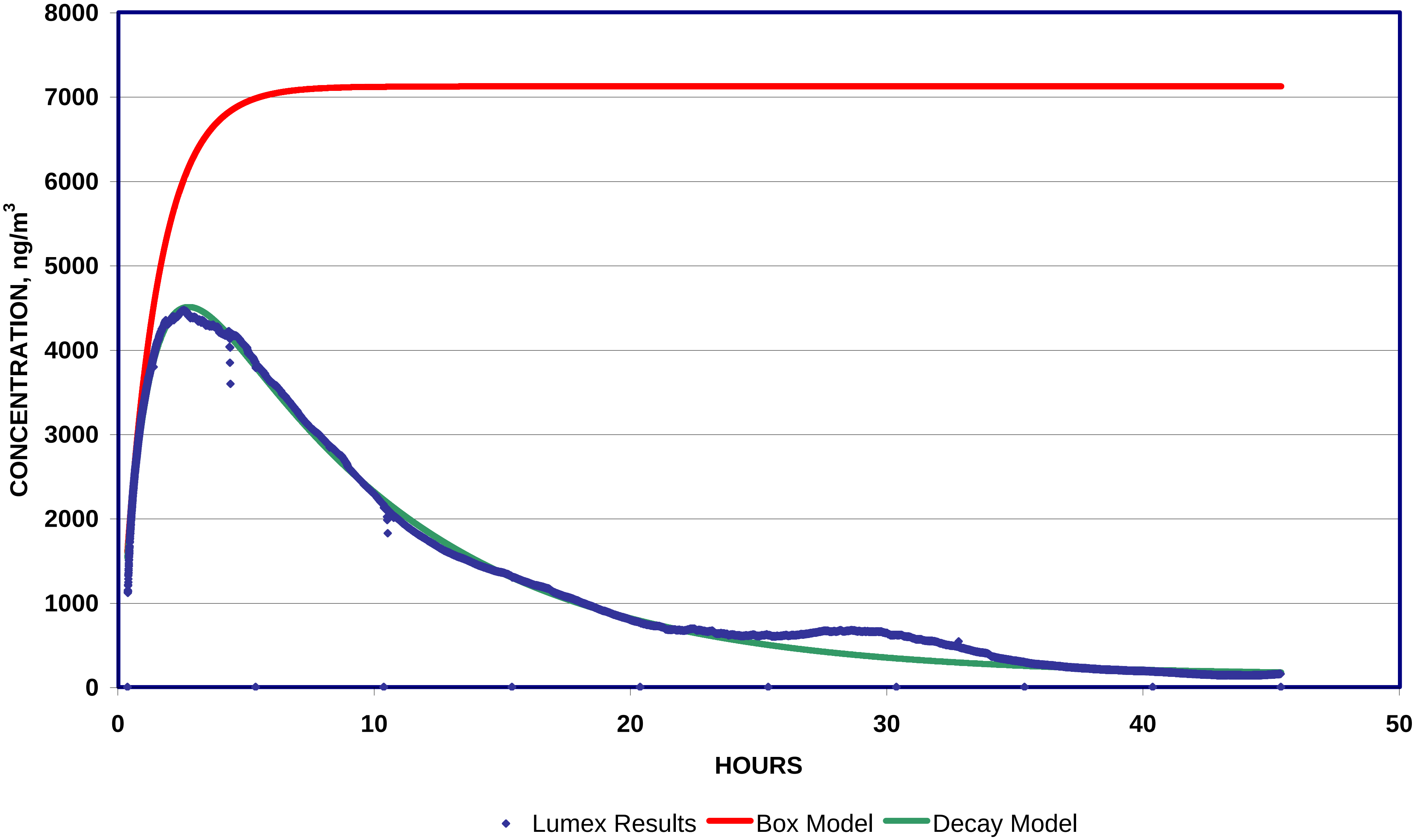


Figure 28
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Tracker Results - 08/07/2002

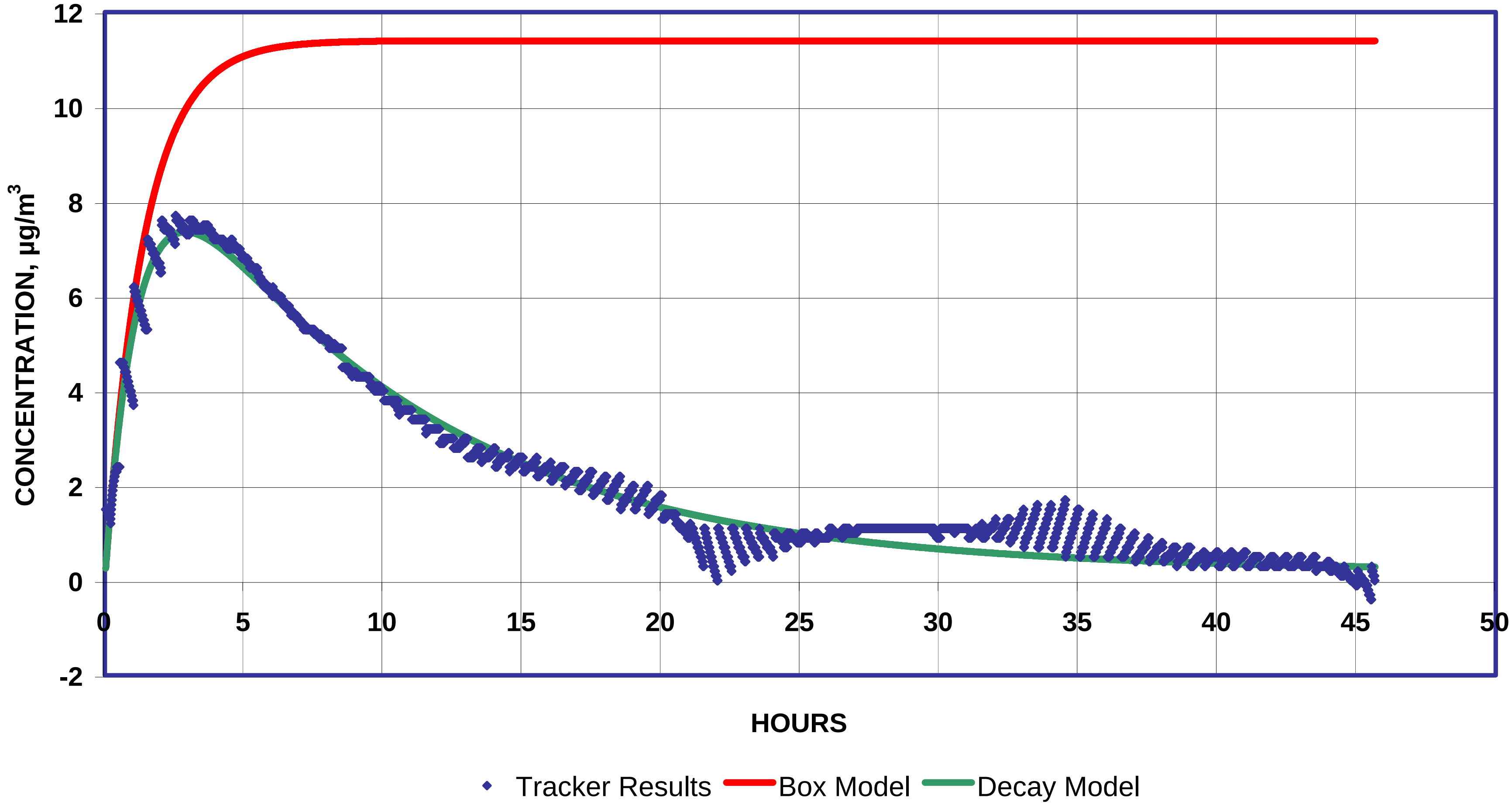


Figure 29
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Lumex Results - 11/25/2002

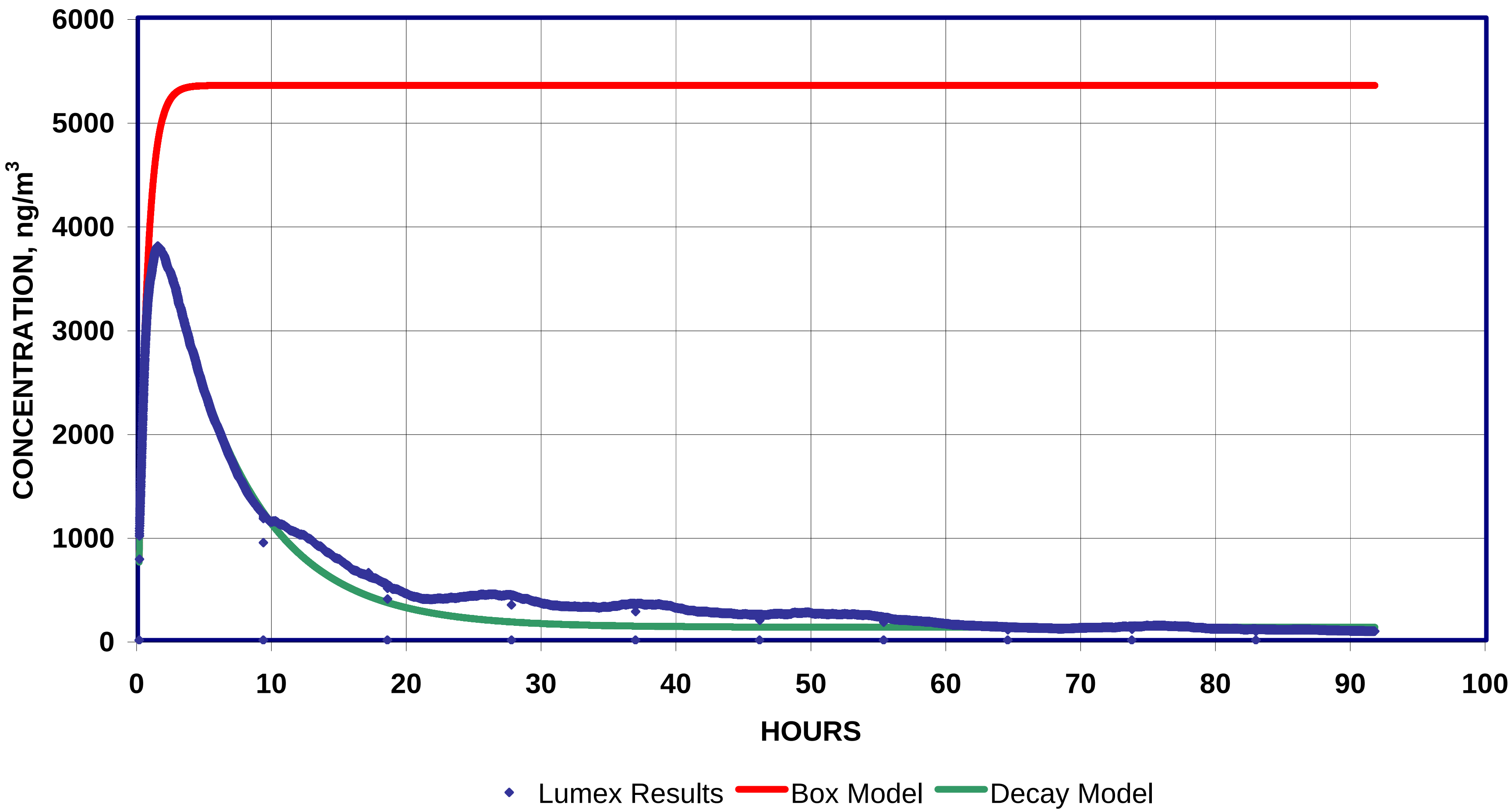


Figure 30
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Lumex Results - 11/14/2002

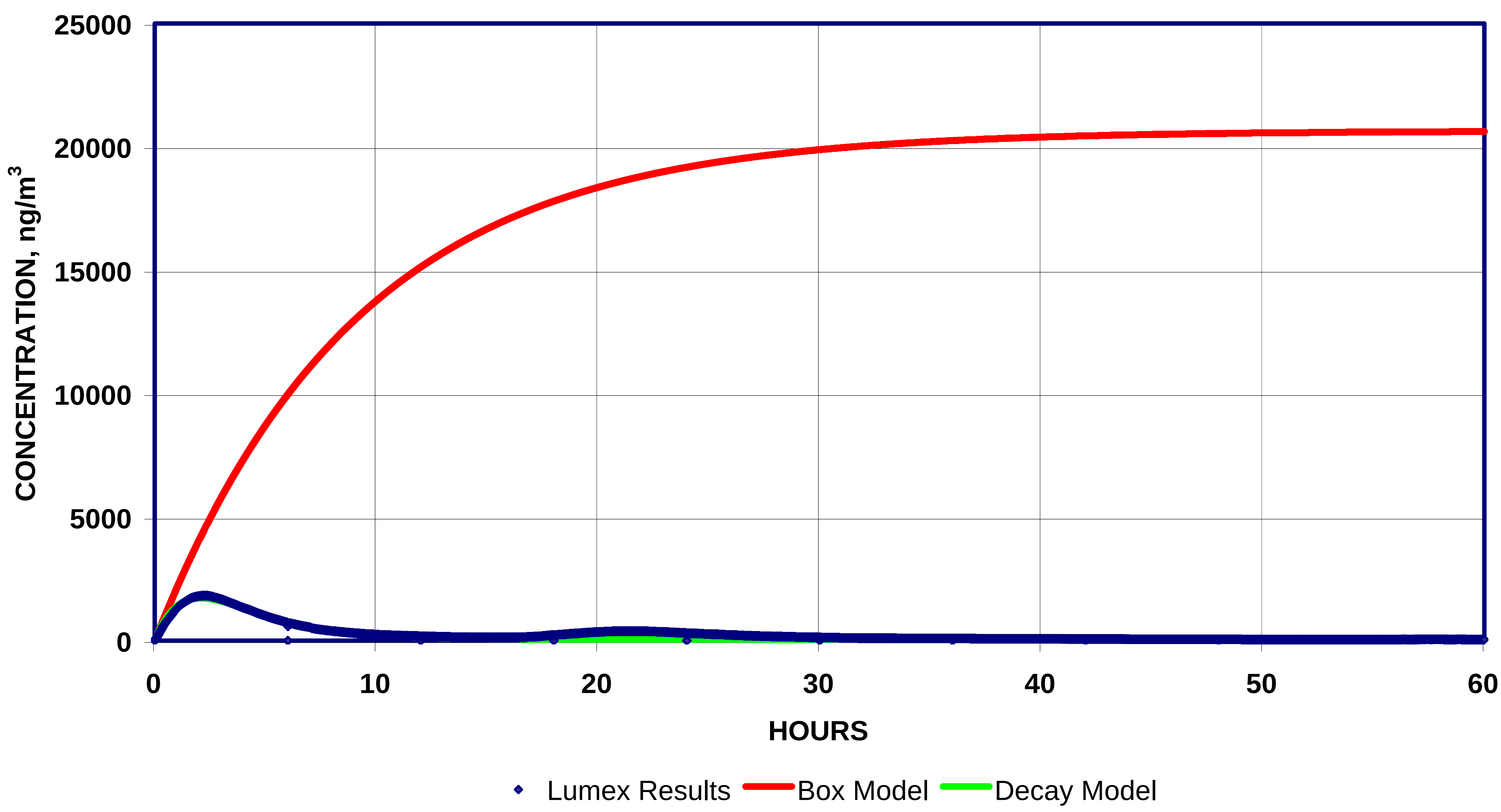


Figure 31
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Lumex Results - 08/19/2002

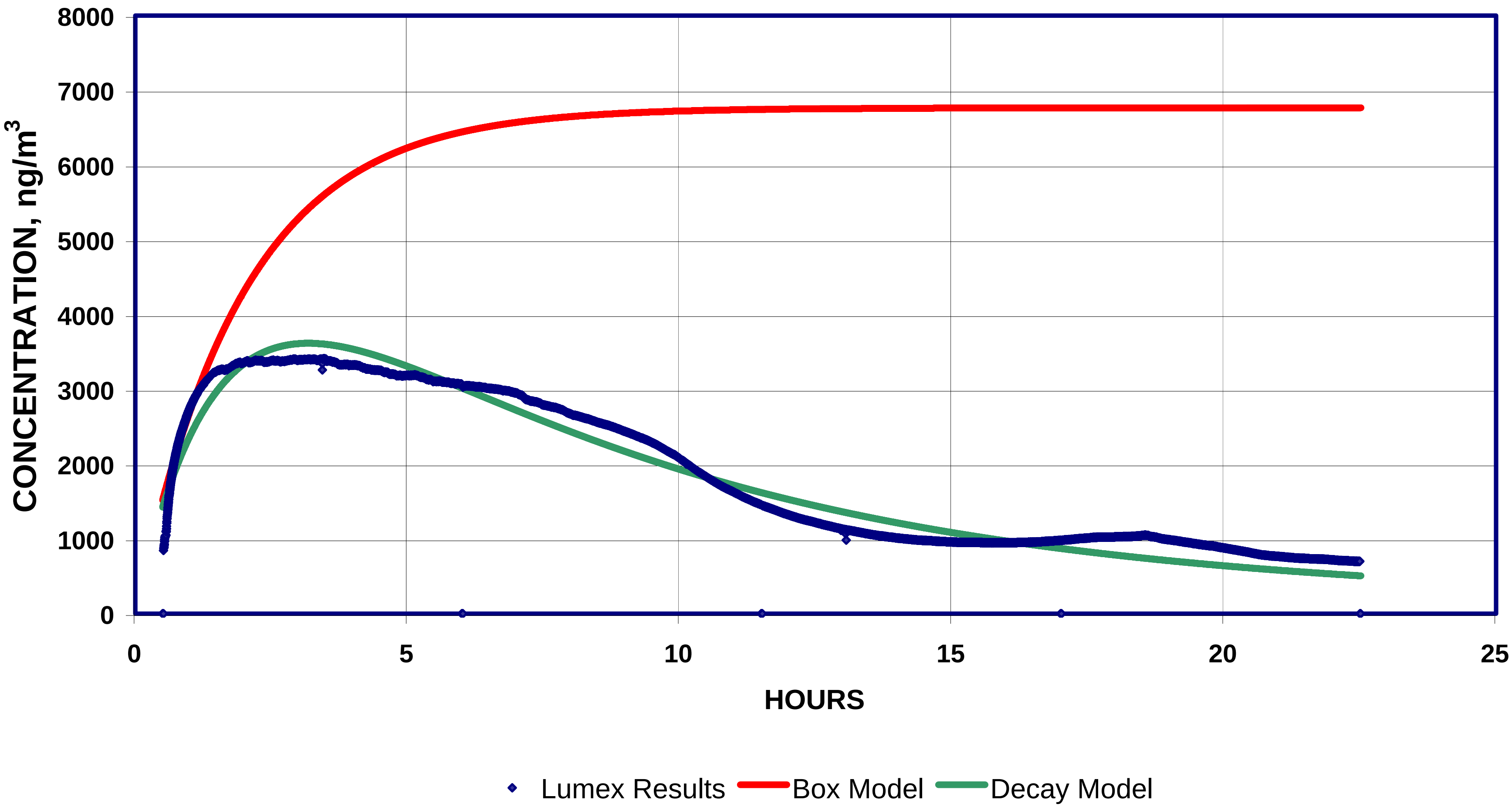


Figure 32
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Lumex Results - 08/19/2002

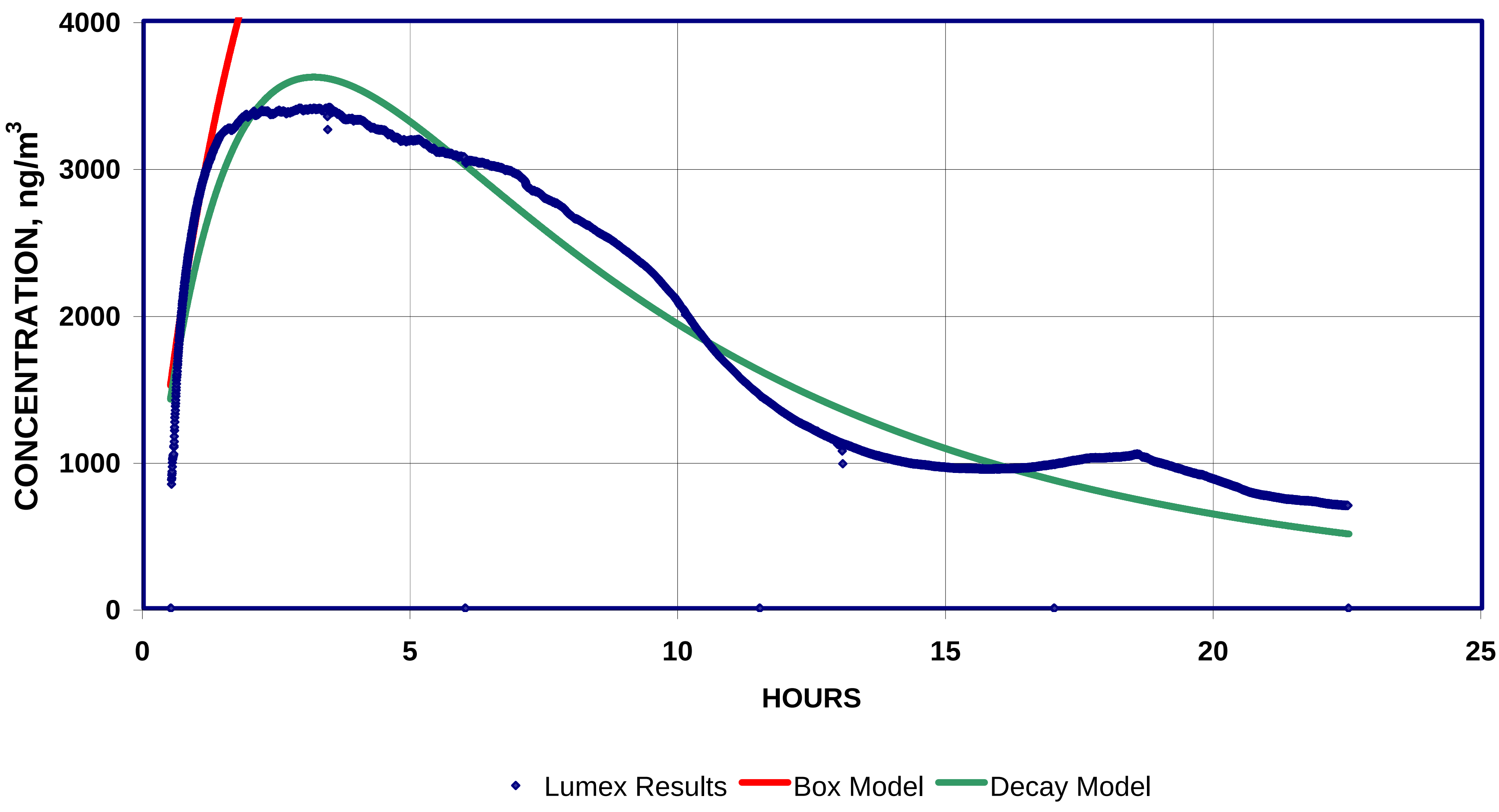


Figure 33
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Tracker Results - 06/11/2002

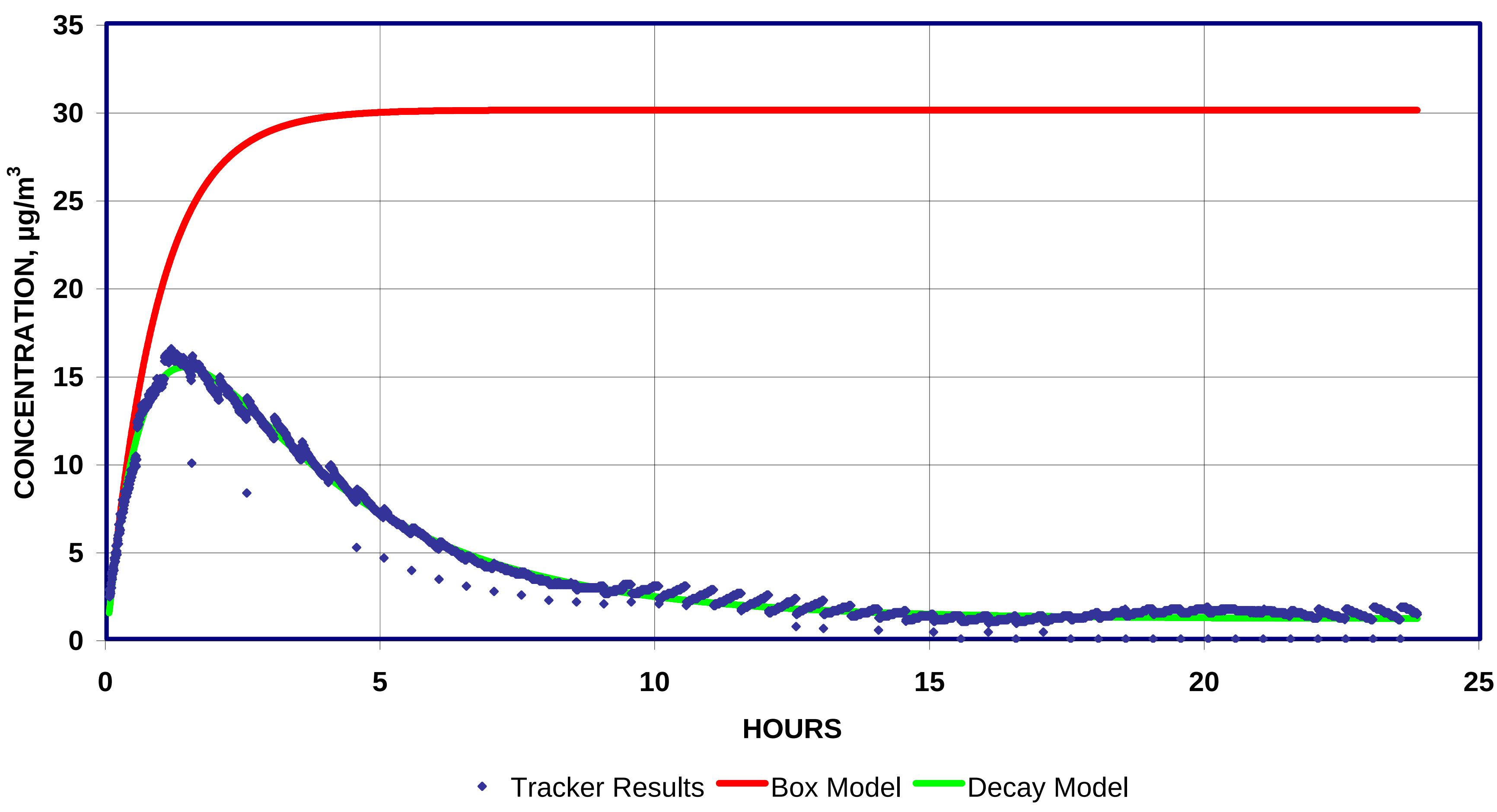


Figure 34
Empirical Model for Indoor Air Mercury Emission
Concentration vs. Time
Tracker Results - 02/28/2002

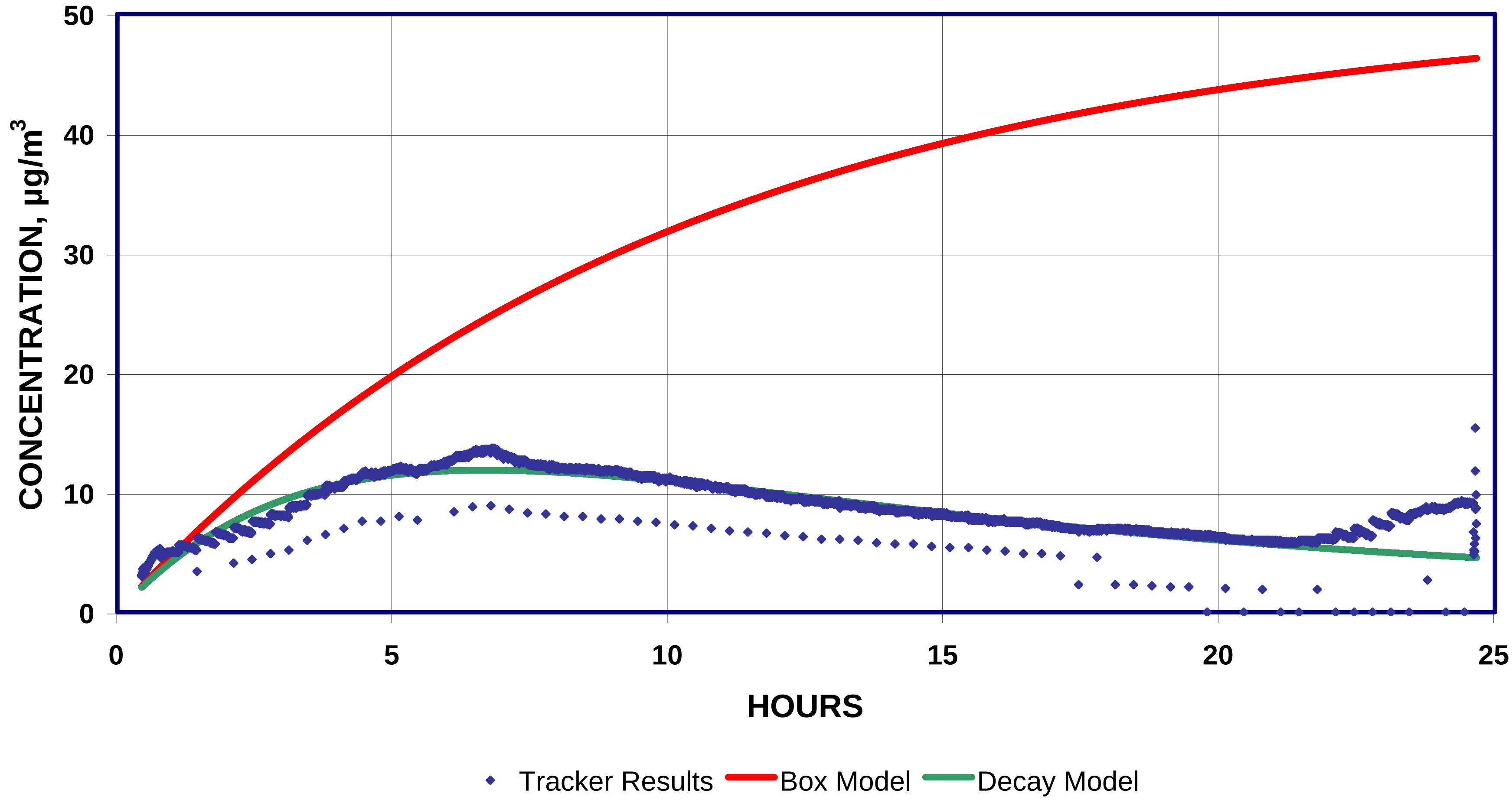


Figure 35
Empirical Model for Indoor Air Mercury Emission
Tracker Results, 0 To 60 Hours - Shaken First 16 Hours

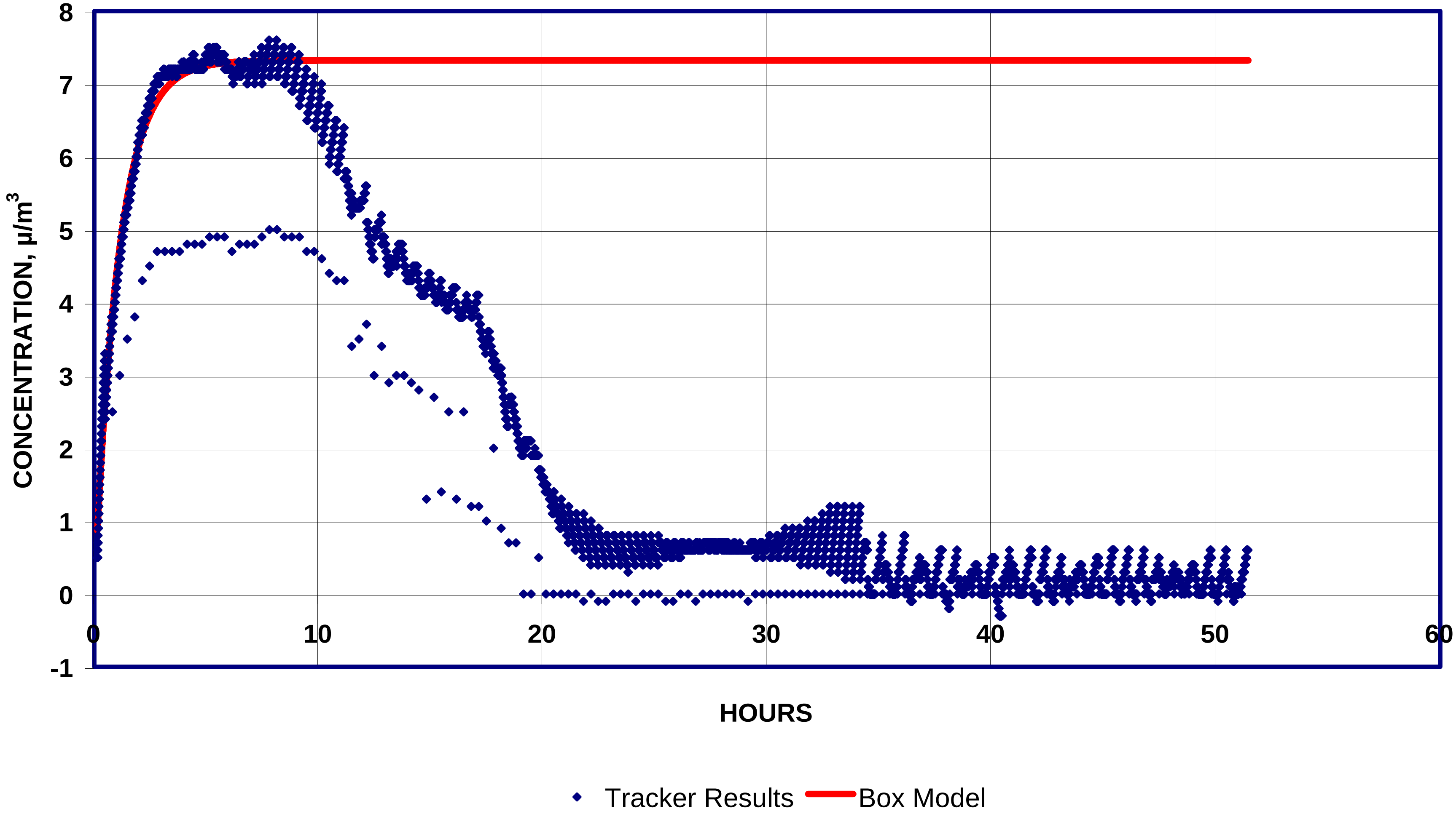


Figure 36
Empirical Model for Indoor Air Mercury Emission
Tracker Results, 0 To 10 Hours - Shaken First 16 Hours

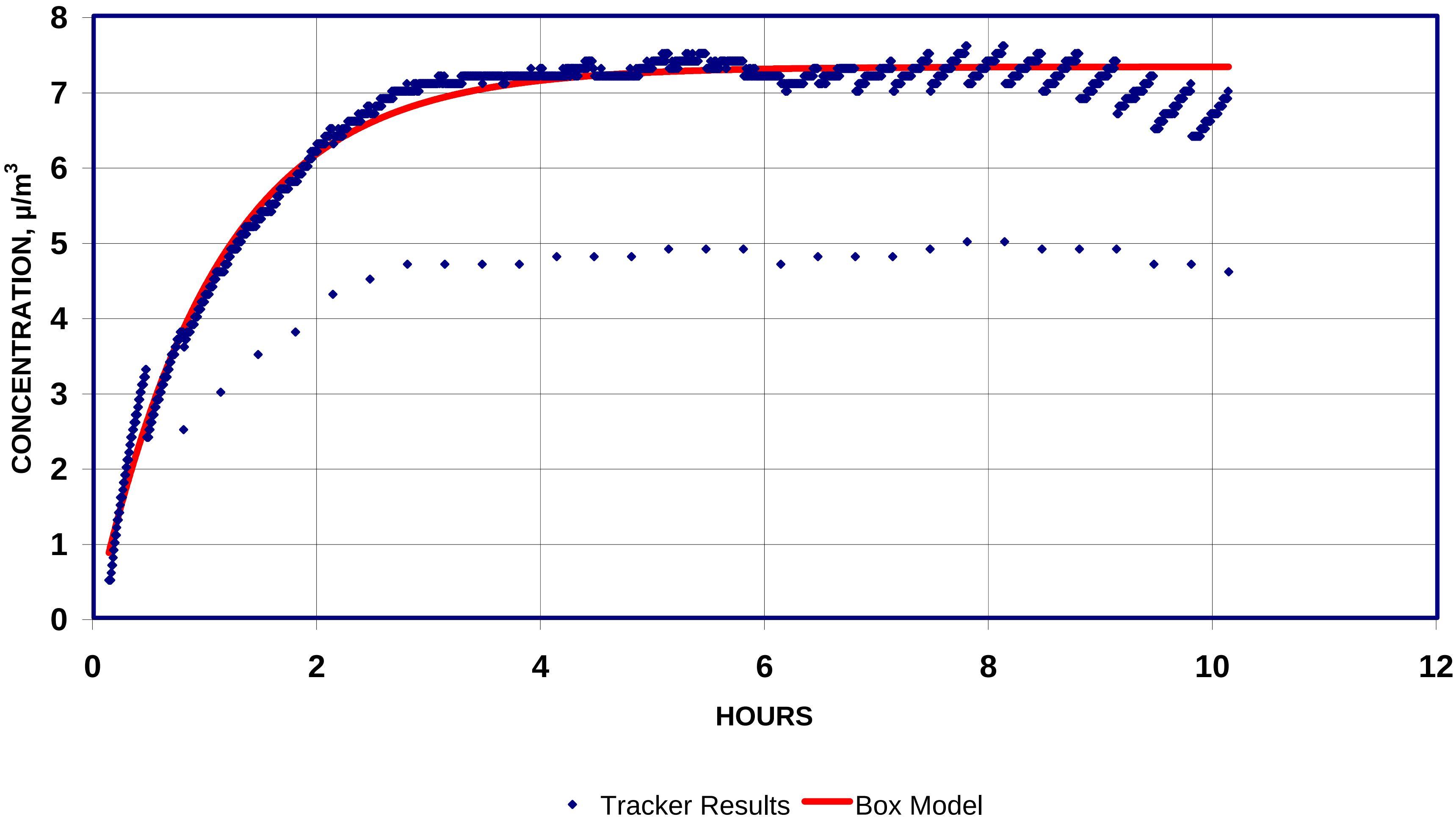


Figure 37
Empirical Model for Indoor Air Mercury Emission
Tracker Results - Delayed Rate Decay

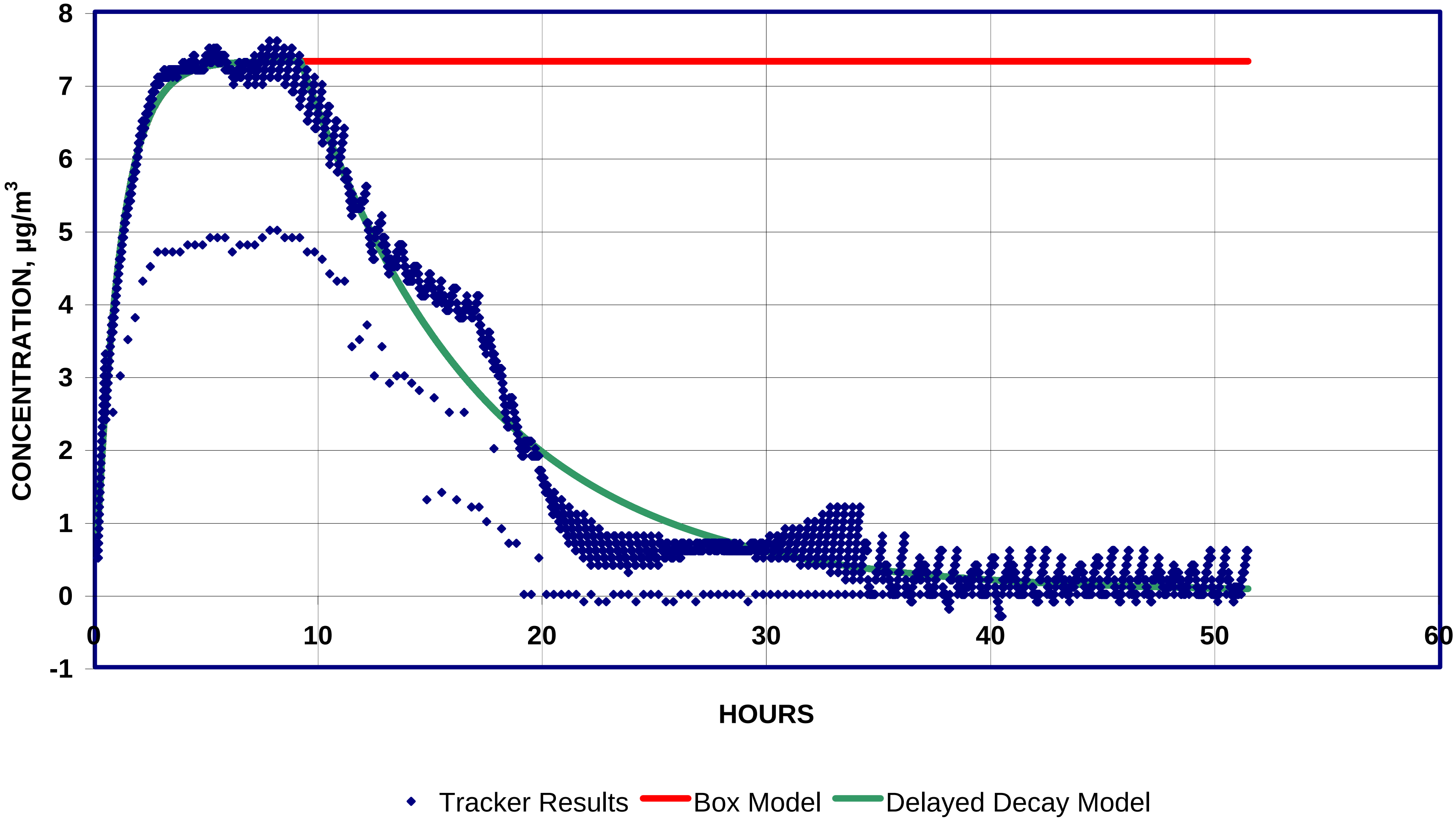


Figure 38
Two Hour Average Tracker Concentration
0 to 400 Hours

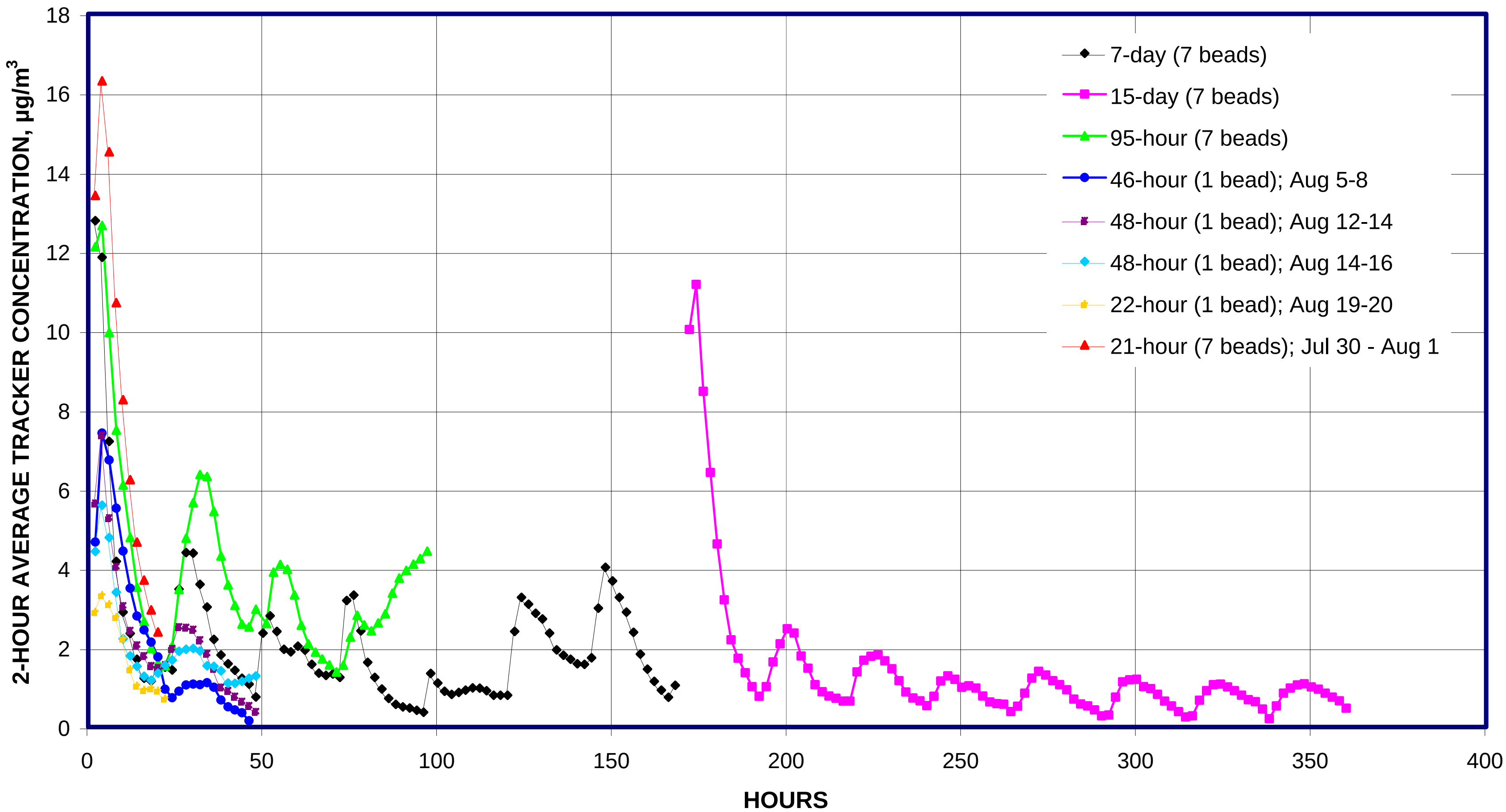


Figure 39
Two Hour Average Tracker Concentration
0 to 100 Hours

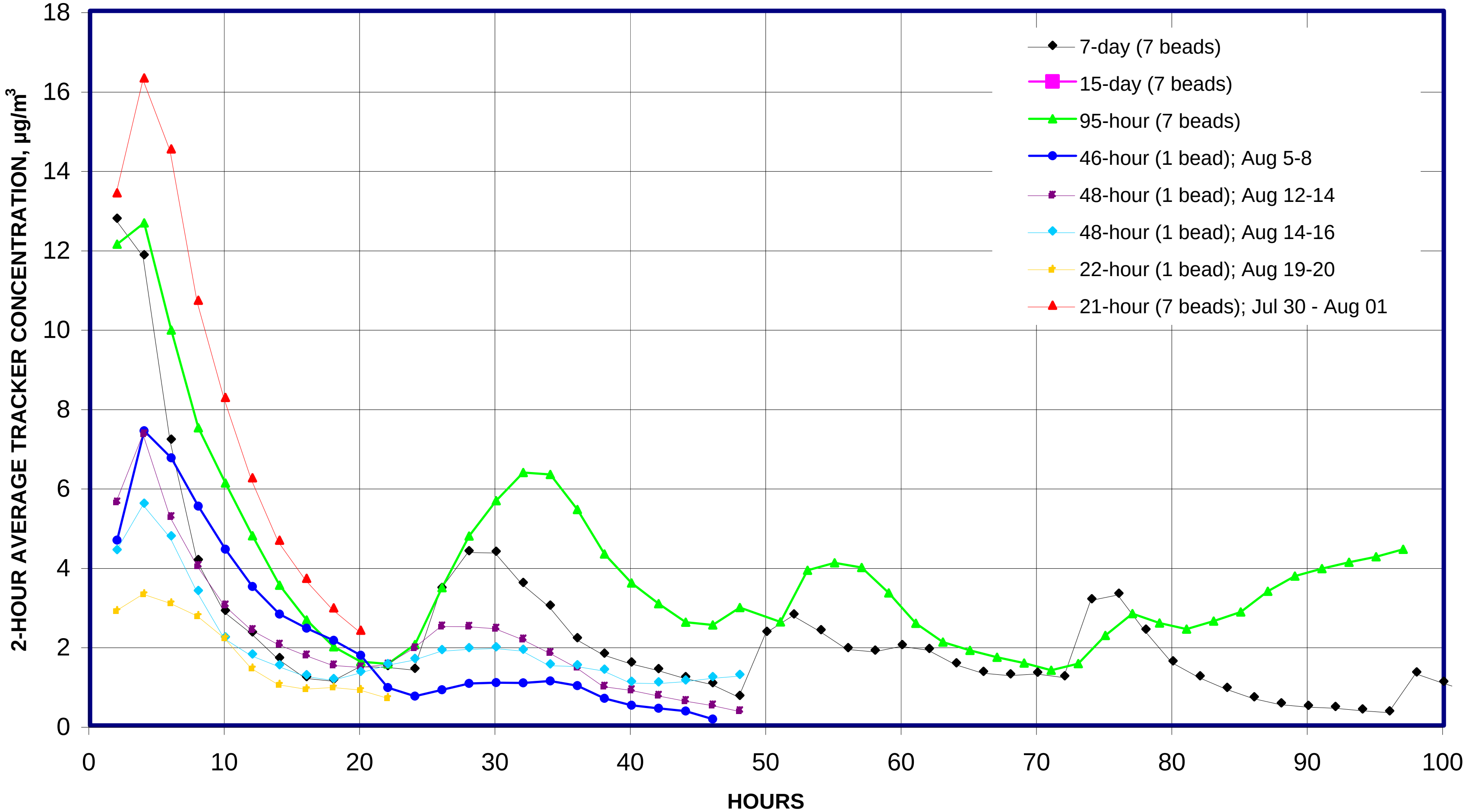


Figure 40
Mercury Emission Rate vs. Time

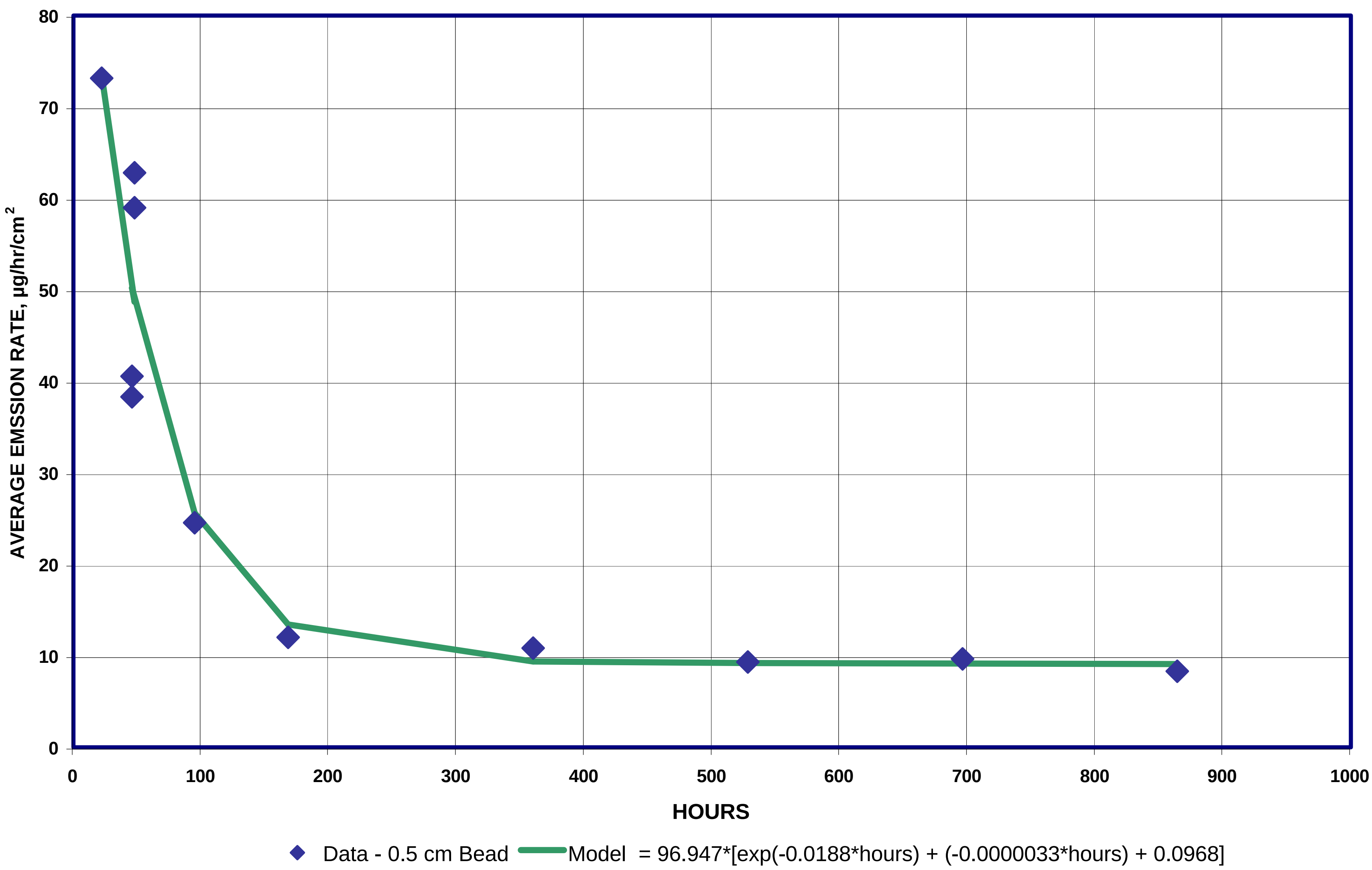


Figure 41
Mercury Emission Rate vs. Time

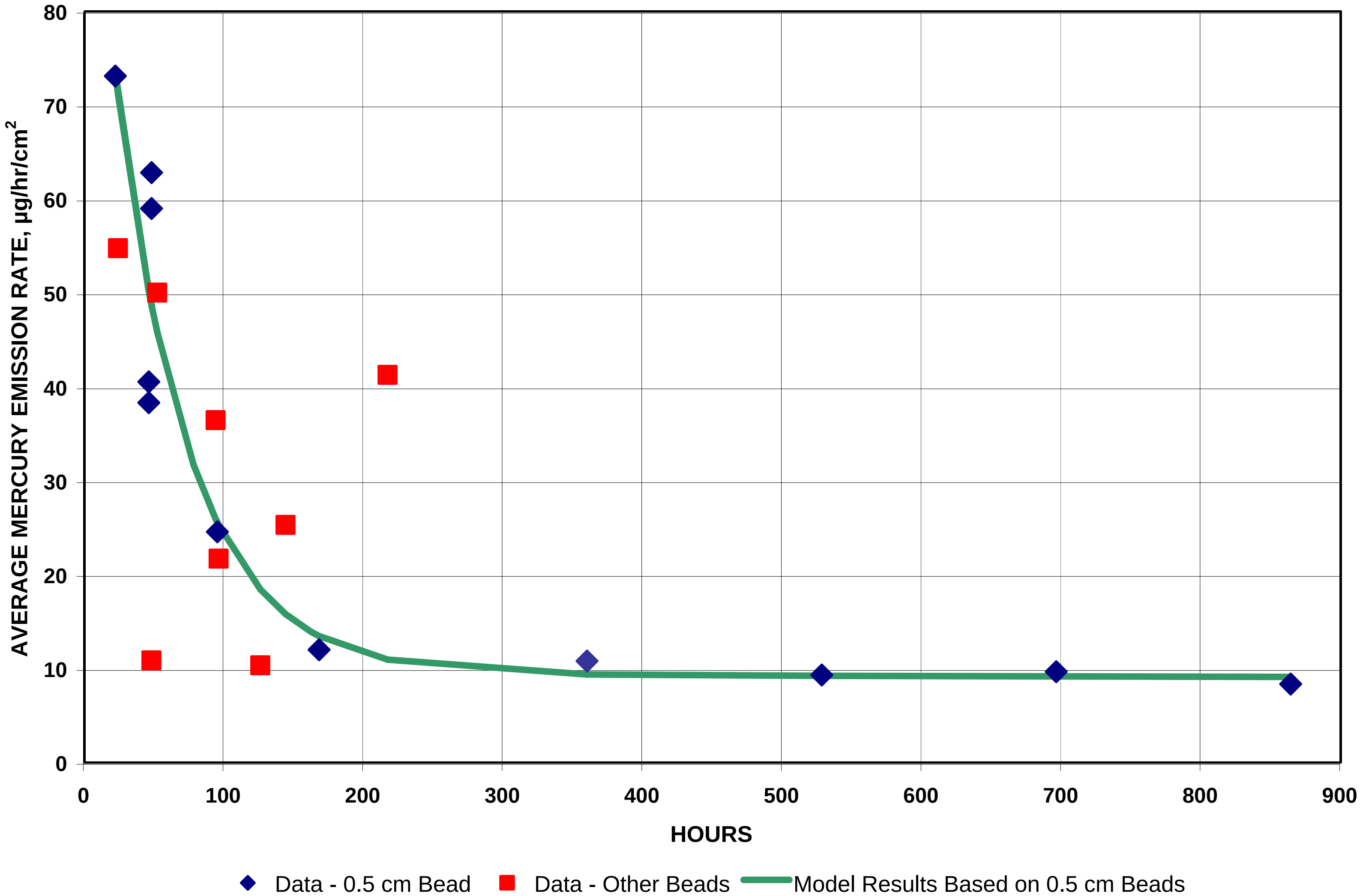


Figure 42
Correlation Between Measured and Predicted Concentration
0.5 cm Bead Size Model

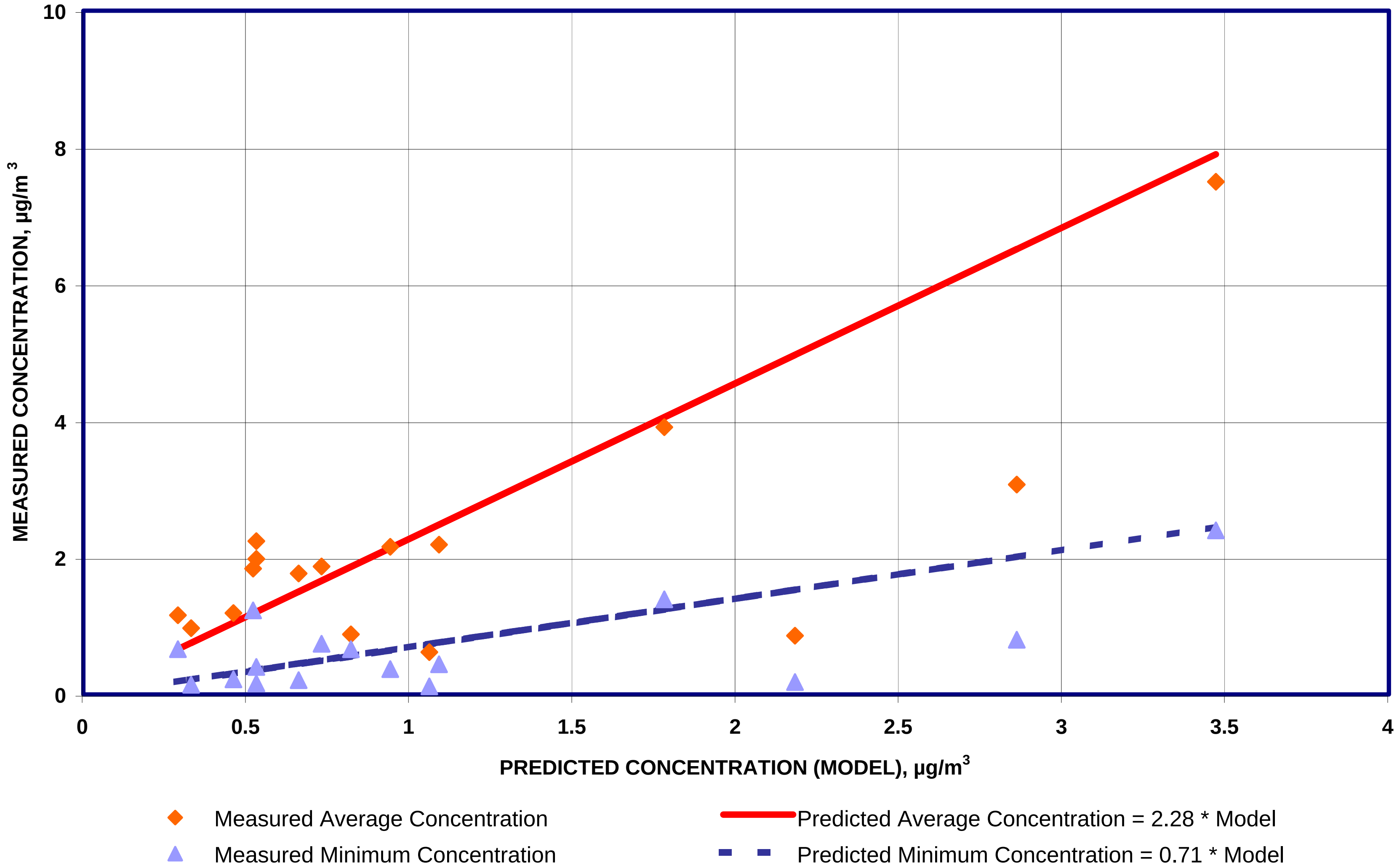


Figure 43
Correlation Between Measured and Predicted Average Concentration
0.5 cm Bead Size Model

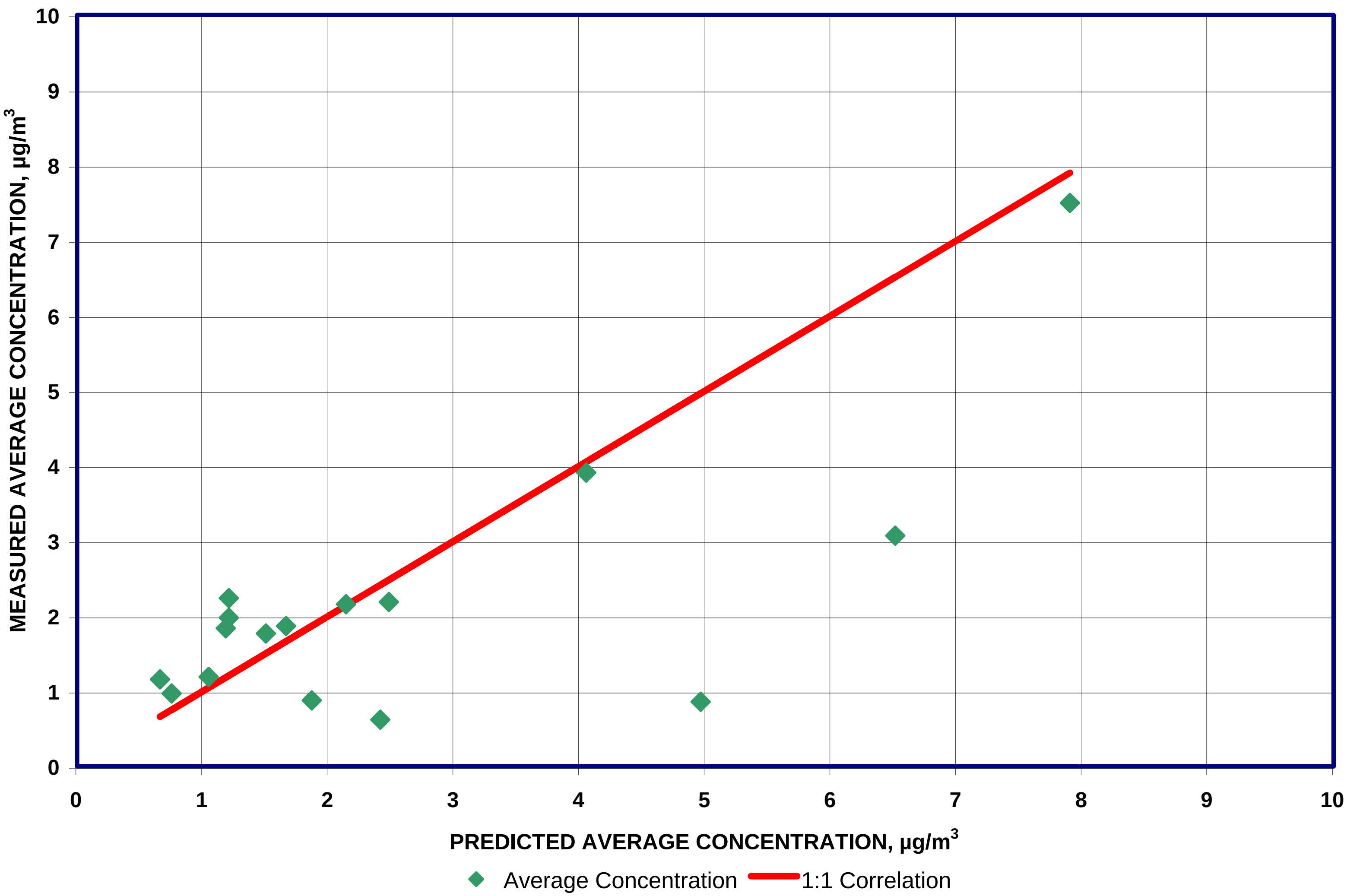
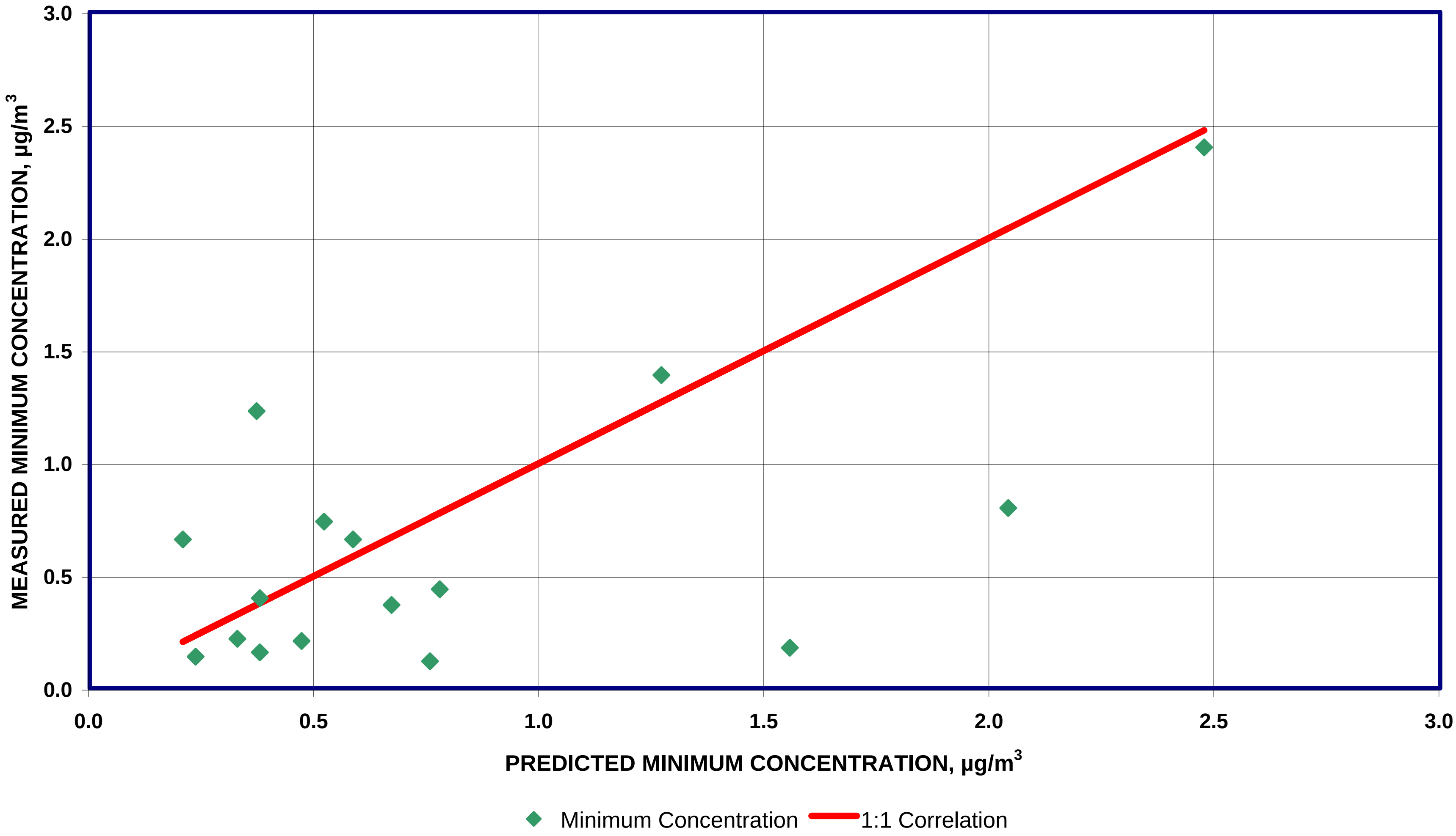


Figure 44
Correlation Between Measured and Predicted Minimum Concentration
0.5 cm Bead Size Model



TABLES

TABLE I
PHYSICAL AND CHEMICAL PROPERTIES OF MERCURY

Name:	Mercury
Synonyms:	Colloidal mercury; Hydrargyrum; Metallic mercury; Quick silver; Liquid silver
CAS#:	7439-97-6
Molecular Formula:	Hg
Molecular Weight:	200.59
Physical State:	Liquid
Appearance:	Silver
Odor:	Odorless
pH:	Not available.
Vapor Pressure:	0.002 mm Hg @ 25^{O}C
Vapor Density:	0.468
Evaporation Rate:	Not available.
Viscosity:	15.5 mPa.s @ 25^{O}C
Boiling Point:	356.72^{O}C
Freezing/Melting Point:	~38.87^{O}C
Auto Ignition Temperature:	Not applicable.
Flash Point:	Not applicable.
NFPA Rating:	(estimated) Health: 3; Flammability: 0; Reactivity: 0
Explosion Limits, Lower:	Not available.
Explosive Limits, Upper:	Not available.
Solubility:	Insoluble
Specific Gravity/Density:	13.59 (water=1)
Decomposition Temperature:	Not available.
Exposure Limits:	
ACGIH:	0.025 mg/m^3 TLV-TWA
NIOSH:	0.05 mg/m^3 TWA
	10 mg/m^3 IDLH
OSHA:	0.1 mg/m^3 PEL Ceiling
Chemical Stability:	Stable under normal temperatures and pressures.
Conditions to Avoid:	High temperatures, incompatible materials.
Hazardous Decomposition Products:	Mercury/mercury oxides.
Hazardous Polymerization:	Will not occur.
RTECS#:	CAS# 7439-97-6: OV4550000
LD50/LC50:	Not available.
US DOT:	Hazard Class: 8
UN Number:	UN2809
Incompatibilities with Other Materials:	Metals, aluminum, ammonia, chlorates, copper, copper alloys, ethylene oxide, halogens, iron, nitrates, sulfur, sulfuric acid, oxygen, acetylene, lithium, rubidium, sodium carbide, lead, nitromethane, peroxyformic acid, calcium, chlorine dioxide, metal oxides azides, 3-bromopropyne, alkynes + silver perchlorate, methylsilane + oxygen, tetracarbonylnickel oxygen, boron diiodophosphide.

References

Simon, M., Jonk, P., Wuhl-Couturier, G., Daunderer, M., Mercury, mercury alloys and mercury compounds. In:
Ullmann's Encyclopedia of Industrial Chemistry (Elvers, B., Hawkins, S., Schulz, G., eds.) Weinheim (Germany: VCH Verlag (1990).
Grier, N., Mercury In: The Encyclopedia of Chemical Elements (Hempel, C. A., ed) New York: Reinhold, (1968).

TABLE 2
Summary of Experimental Design and Objectives

Experiment	Design	Objective
1	o 2.1 g Hg dropped from 3-foot height onto carpet in plastic tray in small room, then tray shaken. Samples initially taken at two locations per room, then decreased to one location per room. o Additional 5.2 g Hg dropped from 3-foot height, fans off, then on. o Additional 5.1 g Hg dropped from 3-foot height, fans on. On Day 3, tray shaken, fans turned off. After 124 hours, shaking stopped, fans on.	Simulate effect of ritual sprinkling of Hg on concentrations in air in residence.
2	2 g Hg placed on carpet in tray, fans off, monitored over 10 days, fans then turned on.	Measure the effect of air movement over Hg beads on resulting Hg concentrations in air.
3	0.7 g Hg from broken thermometer placed on carpet in tray. Monitored over 5 days. On Day 6, tray shaken. Fans on.	Simulate effect of broken thermometer on Hg concentrations in air.
4	o 2.4 g Hg placed in cavity in an unlit candle, two fans on. ?o8.4 g Hg placed into same-sized cavity in an unlit candle.	Determine relative importance of Hg weight vs. surface area on Hg vapor concentration in air.
5	o 2.4 g Hg placed in weighing boat, door between rooms closed, fans on. o 2.4 g Hg placed in weighing boat, connecting door open, fans on. o 8.4 g Hg placed in weighing boat, connecting door closed, fans off. o 8.4 g Hg placed in weighing boat, connecting door closed, fans on.	Determine effect of different Hg weights and surface areas on Hg emissions.
6	o 1 g Hg placed in weighing boat, connecting door closed, fans on, boat shaken for 17 hours. Then shaker stopped and restarted. o Above repeated with 9.6 g Hg in weighing boat.	Determine impact of regeneration of fresh surface via disturbance (shaking) on Hg vapor concentrations in air.
7	o 1 g Hg placed in weighing boat in large room, connecting door closed, fans on with neither blowing over tray. o 4 additional 1-g beads placed in individual weighing boats in large room. o 5 additional 1-g beads placed in individual weighing boats in large room.	Determine Hg vapor concentration in an large room; simulate effect of repeated Hg applications.
8	o Seven 0.5 cm Hg beads placed in individual weighing boats in small room, connecting door closed, fans on. Hg weights measured at t=0, Day 7, 15, 22, 29 and Day 36. o Above repeated with seven individual 0.5 cm (1 g) beads, for 4 days. o Above repeated with seven 1-g beads, for 2 days. o One 1.1 g bead placed in weighing dish, monitored for 2 days. Repeated with 1.5 g and 1.1 g beads.	Measure vapor emission rates and vapor concentration.
9	Ten 0.5 cm Hg beads placed in individual weighing boats in small room, connecting door closed, fans on. Air measurements with two Tracker analyzers, Lumex and NIOSH over 8 hours.	Compare Hg air concentration results obtained from various monitoring methods.
10	o A 5 mg/m^3 gaseous Hg standard analyzed using Lumex equipped with modified software, Tracker, and NIOSH. o 2 g Hg placed in weighing dish in small room, connecting door closed, fans on, monitoring with NIOSH, three Lumex analyzers and two Trackers.	Investigate differences between Lumex and NIOSH results; determine % recovery of standard, use to calibrate real-time analyzers. Check the recalibrated real-time instruments against NIOSH for accuracy.

TABLE 3
Non-Linear Regression Analysis Results for Mercury Concentration vs. Time Data[a]

Data Set	Figure	r^2	Rate of Evaporation, S (µg/hr)	Air Flow Rate from Room, Q (m^3/hr)	Air Exchange Rate, Q/V (hr^{-1})	Time Offset, t_0	Exponential Decay Factor, D	Final Equilibrium Concentration, E (µg/m^3)	Predicted Box Model Concentration, S/Q (µg/m^3)
Lumex 8/5/2002	27	0.998	132	18.6	0.733	0.345	0.117	0.140	7.12
Tracker 8/7/2002	28	0.974	206	18.0	0.709	0.032	0.106	0.200 b	11.4
Lumex 11/25/2002	29	0.998	209	39.1	1.54	0.100	0.167	0.125	5.35
Lumex 11/14/2002	30	0.990	57.6	2.79	0.110	0.000	0.432	0.059	20.7
Lumex 8/19/2002	31 & 32	0.957	87.2	12.9	0.508	0.500 c	0.131	0.160	6.77
Tracker 6/11/2002	33	0.994	829	27.6	1.09	0.047	0.314	1.15	30.1
Tracker 2/28/2002	34	0.910	127	2.51	0.099	0.440	0.116	2.21	50.7

Lumex concentration unit, nanograms per cubic meter (ng/m^3); Tracker concentration unit, micrograms per cubic meter (µg/m^3).
Lumex results were converted to Tracker units.
r^2 = Regression analysis coefficient of determination.

[a] Room volume fixed at 25.37 m^3 for all regression fits.
[b] Final equilibrium concentration fixed at 0.200; calculated for all other data sets.
[c] Constraint limit (0.5 hours) for time offset, t_0; fit parameters may be unreliable.

TABLE 4
Mercury Emission Rate Data Based on Weight Loss

Bead Parameters						Emission - Weight Loss			Mercury Vapor Concentration, µg/m^3			
Starting Weight, g	Number of Beads	Bead Diameter, cm		Effective Surface Area (50%)	Number Hours	mg/bead	µg/hr	µg/hr/cm^2	Calculated with Model	Measured		
		Nominal	Effective*							Max	Min.	Avg.
7.051	7	0.5	0.521	0.4263	864	3.07	24.87	8.34	0.59	NM	NM	NM
7.051	7	0.5	0.521	0.4263	696	2.87	28.86	9.67	0.68	NM	NM	NM
7.051	7	0.5	0.521	0.4263	528	2.10	27.84	9.33	0.66	NM	NM	NM
7.051	7	0.5	0.521	0.4263	360	1.66	32.28	10.82	0.76	12.78	0.21	1.77
7.051	7	0.5	0.521	0.4263	168	0.86	35.83	12.01	0.84	12.78	0.37	2.16
7.0043	7	0.5	0.520	0.4244	95	0.99	72.95	24.55	1.71	12.86	1.39	3.91
6.9842	7	0.5	0.519	0.4236	46	0.79	120.22	40.54	2.80	16.31	2.40	7.50
1.1058	1	0.5	0.538	0.4537	46	0.80	17.39	38.33	0.40	7.42	0.16	2.24
1.1446	1	0.5	0.544	0.4642	48	1.40	29.17	62.83	0.68	7.38	0.40	1.98
1.1256	1	0.5	0.541	0.4591	48	1.30	27.08	58.99	0.63	5.60	1.23	1.84
1.0387	1	0.5	0.526	0.4352	22	0.70	31.82	73.12	0.73	3.35	0.74	1.87
2.4381	1	1	0.700	0.7686	52	2.00	38.46	50.04	0.90	1.70	0.66	0.88
2.4381	1	1	0.700	0.7686	144	2.80	19.44	25.30	0.46	2.45	0.66	1.16
2.4353	1	1	0.699	0.7680	96	1.60	16.67	21.70	0.39	4.15	0.22	1.19
2.4353	1	1	0.699	0.7680	126	1.00	7.94	10.33	0.19	4.15	0.14	0.97
8.3869	1	1.6	1.056	1.7514	94	6.00	63.83	36.45	1.50	3.30	0.12	0.62
9.6181	1	1.5	1.106	1.9188	48	1.00	20.83	10.86	0.49	3.80	0.18	0.86
8.3809	1	1.6	1.056	1.7505	24	2.30	95.83	54.75	2.20	8.65	0.80	3.07
10.000	10	0.5	0.520	0.4243	217	3.80	175.12	41.27	4.12	13.00	0.44	2.19

Room Parameters:
Volume, V (m^3): 25.37
Air Exchanges per Hour, (Q/V): 1.67
Air Flow Rate from the Room,Q (m^3/hr): 42.4

* For a spherical bead:
BW = Bead Weight (g) = (Starting Weight)/(Number of Beads)
BV = Bead Volume (cm^3) = (BW)/13.6 = (4 pi R^3)/3, where, R = radius (cm) and pi = 3.14159
ED = Effective Diameter (cm) = 2R
(BW)/13.6 = (4 pi R^3)/3, therefore, 0.01756 (BW) = R^3
(log10 (0.01756 BW))/3 = log10 R, where, log10 = base 10 logarithm
Therefore, ED = 2R = 2 (10$^{[(\log 10\ (0.01756\ BW))/3]}$)

TABLE 5
Mercury Emission Rate Data Based on Empirical Model

Bead Parameters					Model - Predicted Emission			Mercury Vapor Concentration, µg/m^3				
								Measured			Predicted	
Starting Weight, g	Number of Beads	Effective Bead Diameter, cm	Effective Surface Area (50%)	Number Hours	µg/hr	µg/hr/cm^2	Model Concentration µg/m^3	Max	Min.	Avg.	Avg. Meas.	Min. Meas.
7.051	7	0.521	0.4263	864	27.18	9.11	0.64	NM	NM	NM	1.46	0.46
7.051	7	0.521	0.4263	696	27.34	9.16	0.64	NM	NM	NM	1.46	0.46
7.051	7	0.521	0.4263	528	27.52	9.22	0.65	NM	NM	NM	1.48	0.46
7.051	7	0.521	0.4263	360	28.00	9.38	0.66	12.78	0.21	1.77	1.50	0.47
7.051	7	0.521	0.4263	168	40.14	13.45	0.94	12.78	0.37	2.16	2.14	0.67
7.0043	7	0.520	0.4244	95	76.08	25.61	1.78	12.66	1.39	3.91	4.05	1.27
6.9842	7	0.519	0.4236	46	148.86	50.20	3.47	16.31	2.40	7.50	7.90	2.48
1.1058	1	0.538	0.4537	46	22.77	50.20	0.53	7.42	0.16	2.24	1.21	0.38
1.1446	1	0.544	0.4642	48	22.60	48.69	0.53	7.38	0.40	1.98	1.21	0.38
1.1256	1	0.541	0.4591	48	22.35	48.69	0.52	5.60	1.23	1.84	1.18	0.37
1.0387	1	0.526	0.4351	22	31.98	73.49	0.73	3.35	0.74	1.87	1.66	0.52
2.4381	1	0.700	0.7686	52	35.23	45.84	0.82	1.70	0.66	0.88	1.87	0.58
2.4381	1	0.700	0.7686	144	12.15	15.81	0.29	2.45	0.66	1.16	0.66	0.21
2.4353	1	0.699	0.7680	96	19.43	25.30	0.46	4.15	0.22	1.19	1.05	0.33
2.4353	1	0.699	0.7680	126	14.14	18.42	0.33	4.15	0.14	0.97	0.75	0.24
8.3869	1	1.056	1.7514	94	45.39	25.91	1.06	3.30	0.12	0.62	2.41	0.76
9.6181	1	1.106	1.9188	48	93.43	48.69	2.18	3.80	0.18	0.86	4.96	1.56
8.3809	1	1.056	1.7505	24	124.50	71.12	2.86	8.65	0.80	3.07	6.51	2.04
10.000	10	0.520	0.4243	217	46.48	10.96	1.09	13	0.44	2.19	2.48	0.78

Room Parameters:
Volume, V (m^3): 25.37
Air Exchanges per Hour (Q/V): 1.67
Air Flow Rate from the Room,Q (m^3/hr): 42.4

avg. µg/hr/cm^2 = 96.947 * (e$^{(-0.0188 * \text{hours})}$ + (-0.0000033 * hours) + 0.0968)
avg. µg/hr = (avg. µg/hr/cm^2) * (#beads) * (bead surface area)
S = avg. ug/hr

Model conc. = (S/Q) * (1-((1-e$^{-((Q/V)*\text{hours})}$)/((Q/V)*hours)))
Pred avg. meas. conc = 2.28 * (Model Conc)
Pred min. meas. conc. = 0.71 * (Model Conc)

TABLE 6
Final Mercury Prediction Model Data Entry

Model Based on Bead Parameters

	Entered	
Volume of Room (m^3)	**25.37**	Predicted average concentration = (S/Q) * (1-((1-$e^{-((Q/V)*hours)}$)/((Q/V)*hours)))
Weight of Mercury (g)	**10**	
Average Mercury Droplet Diameter (cm)	**0.5**	
Number of Hours Exposure (24 to 860)	**24**	
Air Exchange Rate (Q/V)	**1.67**	
	Calculated	
Q (V*air leakage) (m^3/hr)	42.37	S = Rate of Hg evaporation (µg/hr) = So * area(cm^2)
Total Volume (weight/density) (cm^3)	0.7353	So = rate of mercury volatilization per unit area of exposed Hg
Average Volume of Each Droplet (cm^3)	0.0654	Q=air flow rate from the room (m^3/hr)
Number of Droplets	11.24	S/Q= equilibrium concentration
Average Surface Area of Each Droplet (cm^2)	0.7850	50 percent surface area emitting
Total Surface Area (cm^2)	8.824	
Surface Area Emitting (cm^2)	4.412	
Average So (µg/hr/cm^2)	71.12	
Average Rate of Mercury Evaporation, S (µg/hr)	313.76	
C (µg/m^3)	7.2	= Predicted average concentration (µg/m^3) for 24 hours

Model Prediction For Exposure Period

Exposure Period	**Exposure Hours**	**Average Concentration, µg/m3**
1 day	24	7.2
2 days	48	5.0
3 days	72	3.6
4 days	96	2.6
5 days	120	2.0
6 days	144	1.6
7 days	168	1.4
14 days	336	1.0
21 days	504	1.0
28 days	672	1.0

PHOTOGRAPHS

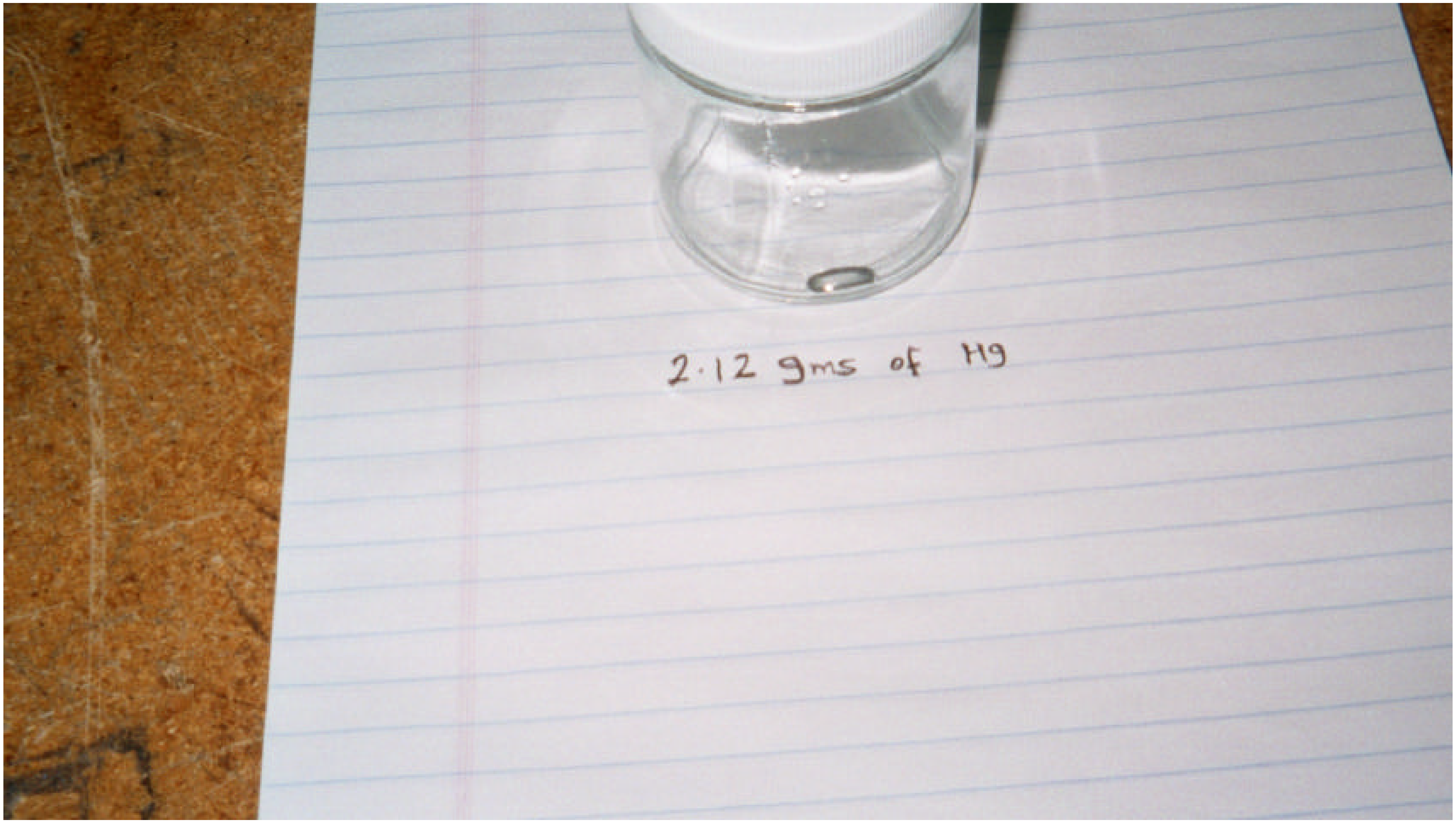
PHOTOGRAPH 1
GOOD LUCK NECKLACE

PHOTOGRAPH 2
CLOSE UP OF THE MERCURY BEAD IN NECKLACE

PHOTOGRAPH 3
OUTSIDE VIEW OF THE TRAILER

PHOTGRAPH 4
SETUP FOR AIR SAMPLING WITH PUMPS AND MONITOR

PHOTOGRAPH 5
MERCURY USED IN EXPERIMENT 1



PHOTOGRAPH 6
MERCURY BEING DROPPED ON CARPET

PHOTOGRAPH 7
MERCURY ON CARPET FOR EXPERIMENT 1

PHOTOGRAPH 8
BROKEN CLINICAL THERMOMETER SIMULATION

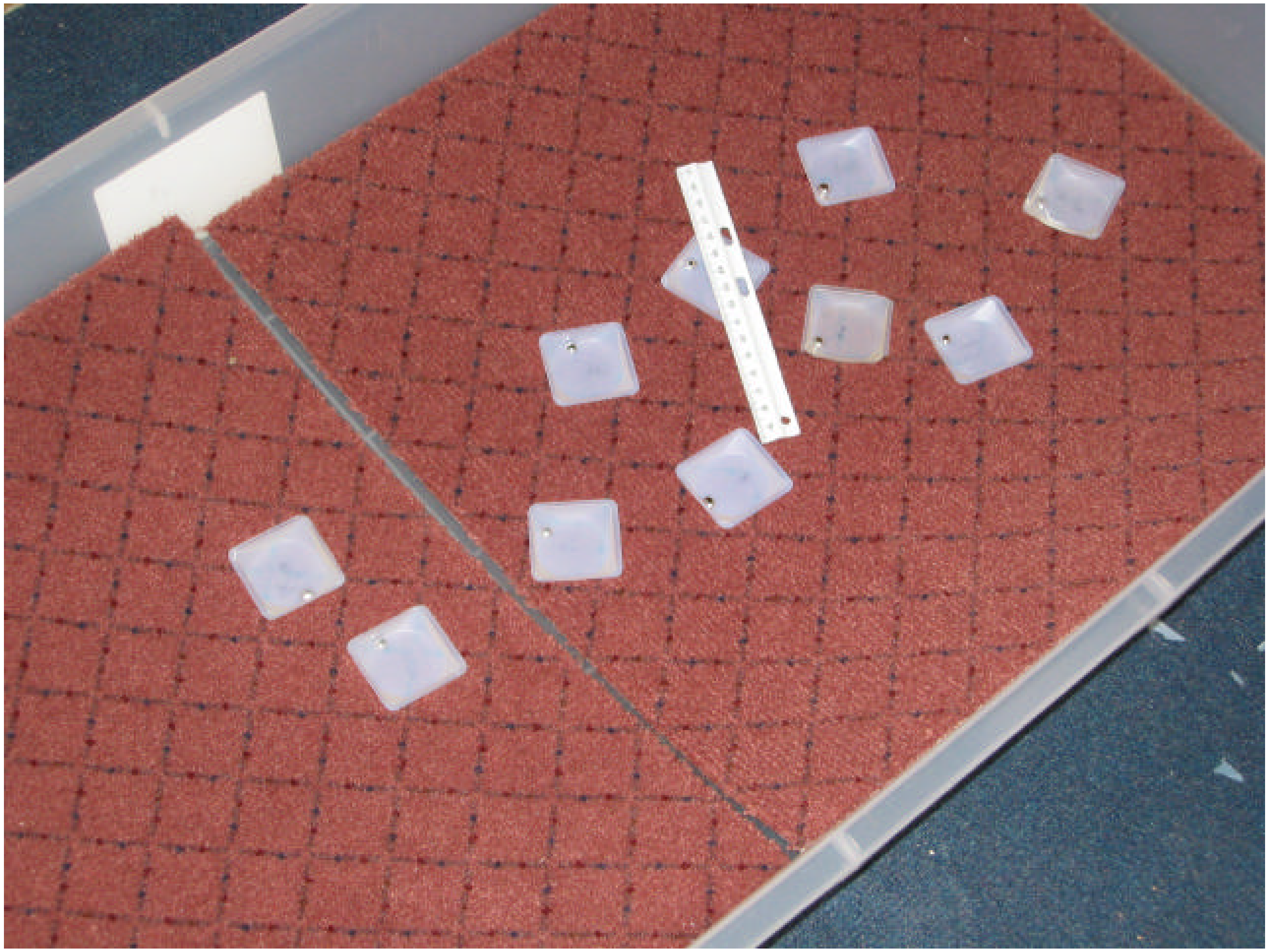
PHOTOGRAPH 9
EFFECT OF SURFACE AREA SIMULATION

PHOTOGRAPH 10
SURFACE AREA REGENERATION SIMULATION

PHOTGRAPH 11

SIMULATION OF RITUALISTIC MERCURY IN LARGE ROOM

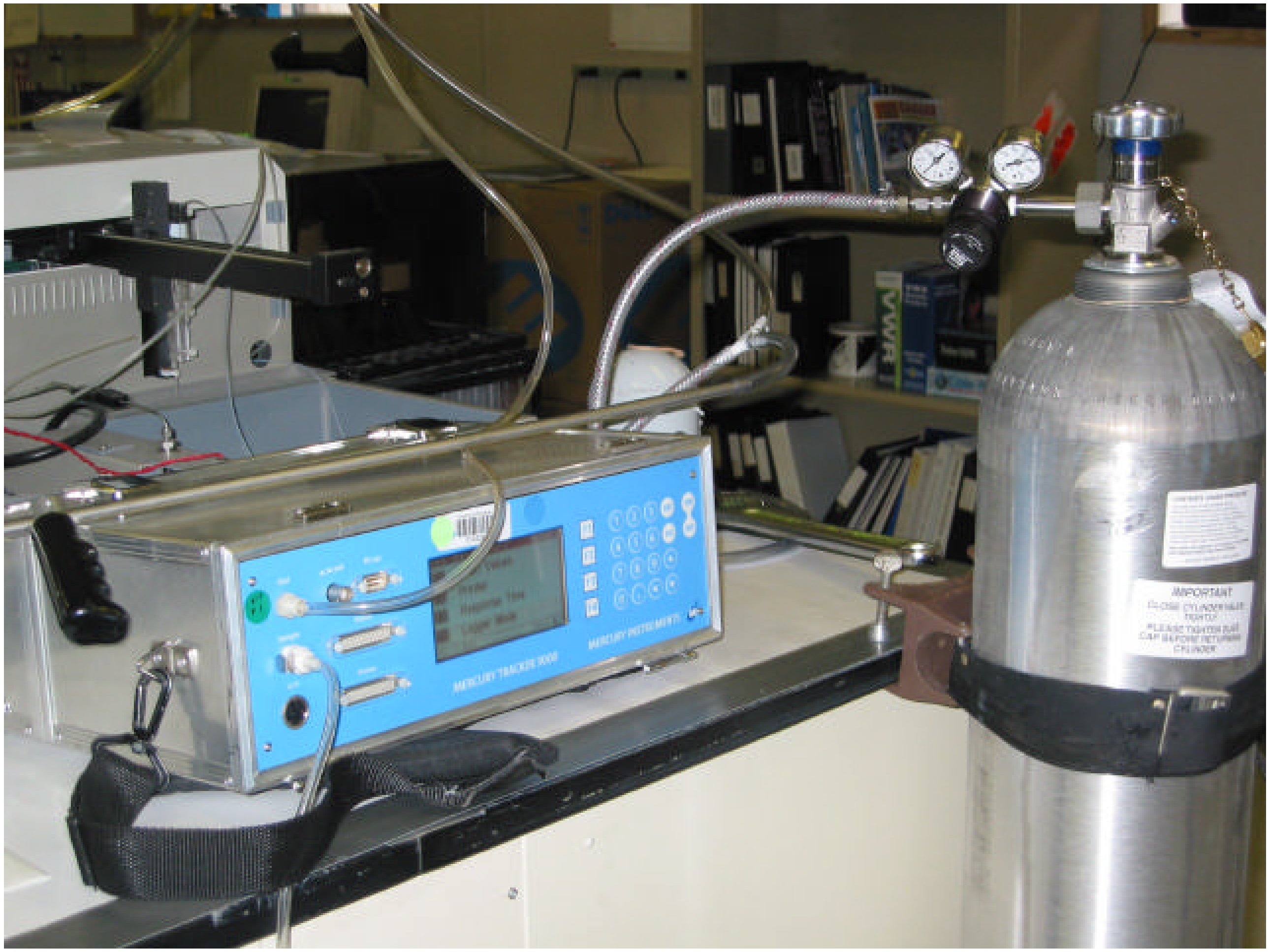
PHOTGRAPH 12
SIMULATION OF RITUALISTIC MERCURY USE IN A LARGE ROOM



PHOTOGRAPH 13
SIMULATION OF RITUALISTIC MERCURY USE IN A LARGE ROOM

PHOTOGRAPH 14
MERCURY VAPOR EMISSION RATE MEASUREMENT

PHOTOGRAPH 15
CALIBRATION OF REAL TIME MONITORING INSTRUMENTS



APPENDIX A
Data Tables

Ritualistic Use of Mercury – Simulation:
A Preliminary Investigation of Metallic Mercury Vapor
Fate and Transport in a Trailer

APPENDIX A: DATA TABLES

TABLE A1

Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1

Mercury Vapor Monitoring in a Trailer

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³				
					NIOSH			TRACKER #2	LUMEX #1
					Center of Table	Near Hg Source	Large Room	Center of Table	
1/14/2002	2.12 grams of mercury was dropped from a height of 3 feet. The large bead splintered into several smaller beads.	7	79.6	20.1	2.8	2.8			
		11	79.0	19.9	1.8	1.9			
		0-12					1.0		
1/15/2002		30	75.9	24.7	1.2	1.5			
		34	75.0	28.5	1.0	0.92			
		23-35					0.42		
1/16/2002		55	81.2	19.9	0.83	0.85			
		59	78.7	19.3	0.46	0.49			
		63	78.0	19.1	0.30	0.29			
		48-60	80.2	20.0			0.38 and 0.34		
1/17/2002		80	80.7	21.6	0.70	0.76			
		84	78.7	21.2	0.41	0.40			
		88	78.1	20.4	0.29	0.24			
		73-85	79.7	21.6			0.30 and 0.31		
1/18/2002	Covered the tray at the end of the day.	101	79.0	25.1	0.27	0.23			
		94-101					0.099 and <0.095		
1/29/2002	Cover of the plastic tray removed after 10 days. Tray was shaken.	103	75.5	35.4	1.2				
		105	86.0	34.5	1.7				
		107	82.0	36.0	1.4				
		109			1.2				
		111			0.71				
		113			0.51				
1/30/2002		115			0.45				
		117			0.37				
		119			0.40				
		101-119					0.40		
1/31/2002	Tray was gently shaken.	126	79.4	29.6	0.57				
		128	79.8	28.4	0.54				
		130	80.1	28.8	0.37				
		132	80.1	29.2	<0.33				
		134	79.7	29.3	<0.33				
		136	80.0	29.3	<0.33				
		138	80.3	29.3	<0.32				
		140	80.2	29.3	<0.34				
		142	80.1	29.1	<0.34				
		124-142					0.088		

TABLE A1

Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1

Mercury Vapor Monitoring in a Trailer

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³				
					NIOSH			TRACKER #2	LUMEX #1
					Center of Table	Near Hg Source	Large Room	Center of Table	
2/4/2002	Tray was gently shaken.	144	65.0	18.0	0.70				
		146			0.70				
		148			0.40				
		150			<0.32				
		152			<0.32				
		154			<0.33				
		156			<0.32				
		158			<0.33				
		160			<0.31				
		142-160					0.12		
2/5/2002	Tray was gently shaken.	168	79.0	19.2	0.30				
		170	80.6	17.5	0.25				
		172	80.5	17.4	<0.17				
		174	78.8	17.4	<0.17				
		176	77.7	17.3	<0.16				
		178	78.1	16.8	<0.17				
		180	77.0	16.4	<0.17				
		182	78.2	16.2	<0.17				
		184	78.5	16.1	<0.17				
		166-184					0.055		
2/6/2002	Tray was not shaken.	188	81.2	18.2	<0.11				
		191	81.5	18.0	<0.11				
		194	79.8	18.4	<0.12				
		197	78.9	18.5	<0.11				
		200	78.4	18.5	<0.11				
		203	78.8	18.4	<0.11				
		206	78.3	18.7	<0.11				
		185-206					<0.021		
2/7/2002	Tray was gently shaken	7	80.1	22.5	0.55		0.27	0.61	
	Real time monitoring comparison study.	7	80.2	22.5	0.55			0.62	
2/8/2002	Tray was shaken.	0-7	84.5	21.2	1.7				0.83
		4-7	84.4	21.3	1.4				0.69

TABLE A1

Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1

Mercury Vapor Monitoring in a Trailer

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. ^{O}F	% RH	CONCENTRATION, µg/m^3				
					NIOSH			TRACKER #2	LUMEX #1
					Center of Table	Near Hg Source	Large Room	Center of Table	
2/11/2001	Additional 2.6 grams of mercury was	8	82.4	20.4	5.5			5.3	
	dropped from a height of 3 ft. On contact with the	14	77.3	17.3	2.4			2.3	
	carpet the bead split into several smaller beads.	2-14					1.5		
2/12/02	(Total 4.72 g of mercury)	20	77.7	15.5	1.5			1.3	
		26	78.0	15.1	1.4			1.4	
		14-26					0.60		
		28	80.5	16.2				4.2	
		30	80.8	17.3				3.9	
		32	81.6	17.5				3.2	
		34	80.7	17.9				2.6	
		36	79.7	18.0				2.2	
		38	79.2	17.9				2.0	
		40	78.4	17.7				1.8	
		42	79.6	17.6				1.6	
		44	79.6	17.6				1.4	
2/13/2002	Additional 5.2 grams of mercury was dropped	7	82.4	15.4	42			38	
	from a height of 3 feet. On contact with the carpet	13	79.4	14.2	27			16	
2/14/2002	the bead split into several smaller beads.	19	78.8	13.1	9.5			7.8	
	(Total 9.92 g of mercury)	3-15					11		
		23	80.0	12.7	7.0			5.9	
		27	83.4	12.9	7.3			6.4	
		15-27					3.5		
		32	78.5	15.3				8.3	
		36	77.5	15.0				5.5	
		40	76.9	16.0				4.2	
		44	76.9	17.0				3.5	
		48	80.3	17.3				3.4	
2/15/2002		53	79.8	21.0	5.7			4.7	2.7
		57	81.9	18.8	4.5			3.8	2.2
2/16/2002		61	78.8	19.2	4.1			3.1	
		65	78.3	21.4	3.3			2.7	
		69	78.5	21.4	3.0			2.6	
		59-71					<0.046		
		73	80.4	17.6				2.7	
		75	79.1	17.0				3.5	

TABLE A1

Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1

Mercury Vapor Monitoring in a Trailer

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, $\mu g/m^3$				
					NIOSH			TRACKER #2	LUMEX #1
					Center of Table	Near Hg Source	Large Room	Center of Table	
		80	82.1	20.9				6.8	
		84	79.1	20.2				3.6	
2/17/2002		88	78.3	19.6				2.4	
		92	78.4	20.4				2.1	
		96	80.7	20.0				1.8	
		100	87.1	18.1				2.2	
		104	81.7	18.3				1.9	
		107	80.2	17.3				1.3	
2/18/2002		111	79.0	16.9				0.99	
		115	78.1	16.4				0.76	
		119	80.0	15.4				0.60	
		123	88.7	14.2				0.88	
		127	81.7	15.9				1.50	
		131	NA	NA				1.30	
		135	NA	NA				0.87	
		138	NA	NA				0.69	
2/19/2002	Fans on.	149	80.1	16.8				2.4	
		151	81.0	17.5				2.0	
		153	80.1	17.5				1.8	
		155	80.0	17.5				1.9	
		157	79.9	17.7				2.1	
		159	79.8	18.1				2.2	
		161	79.8	18.6				2.4	
		163	79.8	19.1				2.5	
		165	80.0	19.7				2.8	
		167	80.4	20.7				3.1	
		169	82.8	21.0				3.4	
2/20/2002	Additional 5.1 grams of mercury were dropped.	3	80.9	24.7	131			139	
	Smaller beads were formed on contact with the car	11	81.2	26.2	7.8			39	
	Fans were left on.	2-10					22		
	(Total 15.02 g of mercury)	14	81.1	30.3	30			30	
		18	81.3	30.4	26			23	
		22	80.5	29.9	17			26	
		10-22					10		

TABLE A1

Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1

Mercury Vapor Monitoring in a Trailer

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. ^{o}F	% RH	CONCENTRATION, µg/m^3				
					NIOSH			TRACKER #2	LUMEX #1
					Center of Table	Near Hg Source	Large Room	Center of Table	
2/21/2002		26	81.1	30.3				25	
		30						16	
		34						8.2	
		38						5.8	
		42						4.2	
		46						4.4	
2/22/2002	Fans were turned off. Tray was gently shaken.	52	80.8	21.0	15			14	
		57	78.8	20.0	7.1			6.3	
		58	79.7	20.4				8.9	
		52-60					5.0		
		62	78.6	19.3	3.6			4.0	
		66	78.2	18.6	4.7			3.0	
		70	97.5	13.9	2.7			3.8	
		60-72					2.0		
2/25/2002	Fans were left off. Tray was not shaken.	77	75.7	36.8	7.0			5.8	
		80	76.9	37.8	5.4			5.5	
		83	86.0	37.3	3.9			4.5	
		73-85	79.9	37.0			2.1	5.2	
		86	91.7	32.1	3.1			4.0	
2/26/2002		89	91.9	31.2	3.0			3.7	
		92	89.4	35.3	2.5			3.3	
		95	88.5	37.0	2.8			3.0	
		85-97	75.7	18.4			1.5	3.4	
2/26/2002	Fans were left off. Tray was not shaken.	102	92.8	21.0	8.4			7.4	
		105	91.9	21.1	11			9.3	
		108	89.5	22.4	8.6			7.7	
		100-112					3.1	7.7	
		111	89.0	22.6	7.4			6.7	
		114	88.2	20.1	5.9			5.2	
		117	86.9	19.0	4.2			4.0	
		120	86.6	19.0	3.5			3.3	
		123	87.5	19.8				4.6	
		112-124					2.6		

TABLE A1

Simulation of Ritualistic Uses of Mercury in a Home: Experiment 1

Mercury Vapor Monitoring in a Trailer

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³				
					NIOSH			TRACKER #2	LUMEX #1
					Center of Table	Near Hg Source	Large Room	Center of Table	
2/27/2002	Fans were turned on. Tray was not shaken.	129	86.0	24.1	12			9.2	5.0
		132	85.2	24.5	14			13	6.2
		135	84.9	24.5	13			11	5.5
		127-139					4.4	10.2	
		138	94.1	14.4	10			9.4	
2/28/2002		141	96.4	9.6	8.8			7.9	
		144	95.0	4.0	7.5			6.7	
		147	92.1	1.7	7.3			6.1	
		139-151					3.4	7.3	

TRACKER #2 Serial Number 0301/168

LUMEX #1 Serial Number S/N 121

TABLE A2
Simulation of Ritualistic Uses of Mercury in a Home: Experiment 2
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	% RH	TEMP. ^{O}F	CONCENTRATION, $\mu g/m^3$		
					TRACKER #2	NIOSH	LUMEX #1
3/27/2002	2.00 grams of Mercury was placed on a	4	15.2	78.3	9.9		
	carpet, inside a plastic tray. Fans off.	8	15.3	77.4	3.9		
3/28/2002		12	16.6	76.5	2.0		
		16	17.2	77.1	1.2		
		20	19.4	81.2	1.5		
		24	18.8	82.5	1.9		
		28	19.1	79.4	1.6		
		32	20.5	78.8	0.90		
3/29/2002		36	21.5	78.5	0.60		
		40	21.4	78.5	0.60		
		44	20.4	82.6	0.66		
	Restart monitoring on 2/29/02, 46 hours	48	20.0	81.6	1.0		
		52	19.9	78.8	0.68		
		48-54			0.63	0.56	
3/30/2002		56	21.1	78.5	0.47		
		60	21.3	78.4	0.44		
		55-61			0.44	0.75	
		64	21.1	79.6	0.61		
		68	20.0	84.6	1.0		
		72	18.9	80.5	1.4		
		76	19.9	78.8	0.89		
3/31/2002		80	21.2	78.7	0.50		
		84	21.5	78.4	0.40		
	Restart monitoring, on 03/31/02	88	21.4	78.5	0.32		
		92	23.5	80.8	0.29		
		96	23.1	80.1	0.35		
		100	23.9	78.8	0.30		
4/1/2002		104	25.2	78.0	0.22		
		108	25.9	78.1	0.18		
		112	25.8	80.7	0.15		
	Restart monitoring, 116 hrs	116	25.1	83.9	0.43		
		120	NR	NR	0.40		
		124	NR	NR	0.25		
		118-126	NR	NR	0.26	0.32, 0.32	

TABLE A2
Simulation of Ritualistic Uses of Mercury in a Home: Experiment 2
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	% RH	TEMP. °F	CONCENTRATION, µg/m³		
					TRACKER #2	NIOSH	LUMEX #1
4/2/2002		128	NR	NR	0.14		
		132	NR	NR	0.09		
		136	NR	NR	0.08		
		140	NR	NR	0.32		
		144	NR	NR	0.28		
		148	NR	NR	0.26		
4/3/2002		152	NR	NR	0.26		
		156	NR	NR	0.29		
	Fan turned on at 11.15 AM	160	NR	NR	1.81		
	Restart monitoring 162	164	NR	NR	4.9		
		168	28.4	80.4	3.0		
		172	24.5	79.9	1.1		
4/4/2002		176	21.9	79.9	0.65		
		180	20.8	80.3	0.45		
		184	21.9	80.9	0.58		
		188	21.5	81.1	0.50		
		192	19.5	80.6	0.44		
		196	17.8	80.2	0.30		
4/5/2002		200	16.9	79.4	0.24		
		204	16.6	81.2	0.16		
		206	17.4	80.8	0.26		

TRACKER #2 Serial Number 0301/168
LUMEX #1 Serial Number S/N 121

TABLE A3

Broken Thermometer Simulation: Experiment 3

Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³		
					TRACKER #2	NIOSH	LUMEX #1
4/23/2002	Mercury from a clinical thermometer	4	84.9	17.9	7.2		
	was dropped on a new mercury free carpet.	8	84.1	16.4	3.6		
	carpet. Connecting door was closed and	12	81.3	15.8	1.1		
	and fans were left on. Weight of mercury: 0.7143 grams.	16	80.5	15..4	0.45		
		20	84.0	15.8	0.33		
		24	83.2	17.9	0.34		
		28	84.2	17.4	0.30		
		32	81.9	16.3	0.28		
		36	81.4	16.8	0.18		
		40	81.0	17.9	0.14		
		44	83.1	19.5	0.14		
		48	82.5	21.6	0.17		
4/25/2002	Monitoring at 48 hours	52	81.8	30.4	0.17		
		56	81.6	28.0	0.21		
		60	80.2	26.3	0.17		
		52-60			0.19	0.23, 0.23	
		64	79.7	25.0	0.17		
4/26/2002	Fans were left running. Monitoring started 66 hrs.	68	85.9	23.7	0.23		
		72	86.0	23.8	0.25		
		76	85.6	22.5	0.32		
		80	82.1	21.8	0.22		
		84	81.9	20.9	0.14		
		88	80.7	20.3	0.09		
		92	84.2	20.4	0.13		
		96	83.8	22.7	0.07		
		100	83.8	23.1	0.15		
		104	81.8	23.9	0.16		
		108	81.3	26.5	0.10		
		112	81.0	33.8	0.13		
		116	81.4	42.9	0.17		
4/28/2002	Fans were left on and connecting tray shaken	124	82.0	45.9	0.42		
	door was left open.	128	82.1	45.8	0.58		
		132	81.3	44.0	0.72		
		136	82.4	40.3	0.69		
		140	83.6	37.0	0.60		
		144	85.2	34.0	0.49		
		148	83.6	32.3	0.43		
		152	81.7	29.6	0.38		
		156	80.7	28.0	0.27		
		160	79.8	26.9	0.21		
		162	87.3	24.9	0.08		

TRACKER #2 Serial Number 0301/168

LUMEX #1 Serial Number S/N 121

TABLE A4
Effect of Surface Area Simulation : Experiment 4
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³		
					TRACKER #2	NIOSH	LUMEX #1
4/5/2002	2.4430 grams of mercury placed in a	4	82.3	16.7	1.7		
	cavity bored into a candle, 0.635 cm ID.	8	82.2	16.5	1.0		
	Fans on.	12	79.3	16.4	0.61		
		16	78.3	16.3	0.39		
	Final weight of mercury 2.4351 g	20	78.2	16.2	0.32		
	Loss of mercury 0.0079 g	24	84.2	16.2	0.33		
4/6/2002	Restart Monitoring after 24 hrs	28	84.4	16.1	0.90		
		32	82.5	15.6	0.58		
		36	80.5	14.5	0.40		
		40	79.0	13.6	0.34		
		44	78.5	13.4	0.19		
		48	83.1	14.0	0.28		
4/7/2002		52	83.2	14.9	0.33		
		56	81.7	14.8	0.36		
		60	79.8	15.7	0.31		
	Final weight of mercury 2.4327 g	64	79.6	16.7	0.27		
	Loss of mercury 0.0022 g	68	80.0	18.0	0.28		
4/8/2002	Restart Monitoring after 70 hrs	72	82.8	20.0	0.36		
		74	83.4	22.0	0.80		
		76	83.4	22.1	0.79		
		80	82.0	22.9	0.68		
		84	82.1	23.6	0.49		
		88	81.9	26.0	0.41		
		92	83.8	27.3	0.40		
		94	84.9	29.9	0.38		
4/9/2002		98	84.8	30.6	0.38		
		102	83.6	35.0	0.43		
		106	83.0	36.4	0.43		
		110	83.4	37.0	0.43		
		114	83.6	31.3	0.38		
		118	86.1	26.4	0.37		
4/10/2002	Monitoring started 120 hrs.	122	84.2	27.5	0.38		
		126	84.3	24.6	0.46		
		130	82.1	23.5	0.36		
		124-130			0.44	0.47; 0.46	
		134	81.6	22.8	0.28		
		138	83.2	21.7	0.28		
		142	84.3	24.5	0.30		
4/11/2002		146	82.3	24.5	0.26		
		150	80.8	24.3	0.28		
		154	80.7	24.2	0.26		
	Final weight of mercury 2.4381 g	158	80.2	25.2	0.24		
	Loss of weight 0.0054 g	162	81.1	25.7	0.24		

TABLE A4
Effect of Surface Area Simulation : Experiment 4
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. ^{O}F	% RH	CONCENTRATION, µg/m^3		
					TRACKER #2	NIOSH	LUMEX #1
4/30/2002	Mercury (8.3911 grams) placed inn a cavity, 0.635 cm ID, located on top of a commercial candle. Fans were running and connecting door was closed.	4	85.7	26.3	0.96		
		8	84.9	27.7	0.52		
		12	83.7	30.0	0.34		
		16	83.2	30.4	0.22		
		20	82.1	30.3	0.18		
4/31/2002		24	86.0	28.1	0.17		
		28	88.1	28.9	0.25		
		32	88.8	27.7	0.28		
		36	84.2	26.3	0.36		
		40	82.9	27.8	0.16		
		44	83.3	29.1	0.13		
		46	85.1	29.4	0.01		
5/2/2002	Monitoring continued	50	82.1	35.7	0.34		
		54	83.4	37.2	0.16		
		56	84.9	38.6	0.19		
		60	83.2	39.2	0.24		
		64	83.2	38.8	0.28		
		68	83.2	37.4	0.29		
		72	86.4	30.5	0.15		
5/3/2002	Final weight of mercury 8.3869 grams	76	85.9	28.5	0.23		
	Loss of weight 0.0042 g	78	87.0	26.8	0.09		

TRACKER #2 Serial Number 0301/168
LUMEX #1 Serial Number S/N 121

TABLE A5
Effect of Surface Area Simulation : Experiment 5
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. ^{o}F	% RH	CONCENTRATION, µg/m^3		
					TRACKER #2	NIOSH	LUMEX #1
4/12/2003	2.4381 gram mercury bead placed in	4	81.8	28.3	1.7		
	a 1 x 1 inch plastic weighing boat.	8	81.6	30.6	1.0		
	Fans were left on. Diameter of mercury	12	81.6	32.3	0.69		
	bead, 1 cm.	16	82.0	33.2	0.72		
		20	81.8	33.9	0.86		
		24	83.4	34.6	0.85		
		28	85.5	38.2	1.0		
		32	84.3	39.3	0.98		
		36	82.3	39.0	0.78		
		40	82.7	38.6	0.72		
		44	82.6	39.0	0.75		
	Final weight at end 2.4361	48	85.7	36.7	0.66		
	Loss in weight 0.0020	52	88.5	37.4	0.74		
4/14/2002	Same bead weighing 2.4361 g placed in	56	84.8	38.8	1.3		
	A 1 x 1 inch plastic weighing boat.	60	82.3	39.4	1.3		
	Fans were left on.	64	82.7	39.5	0.98		
		68	82.6	41.0	0.96		
		72	83.6	40.0	0.96		
		76	87.1	41.5	0.98		
		80	92.6	39.4	1.2		
		84	88.0	39.1	1.4		
		88	82.4	39.9	0.99		
		92	82.8	39.2	0.78		
		96	84.4	38.5	0.69		
		100	95.7	37.7	1.1		
4/16/2002	Restart Hg Monitoring after 102 hrs	104	101.2	36.9	2.2		
		108	94.3	36.5	2.3		
		112	86.1	39.0	1.6		
		116	82.6	40.3	1.0		
		120	88.8	37.5	0.7		
		124	100.8	36.0	1.4		
		128	105.2	32.0	2.4		
		132	96.8	31.7	2.5		
		136	88.5	33.0	1.7		
		140	83.2	35.1	1.2		
		144			0.73		

TABLE A5
Effect of Surface Area Simulation : Experiment 5
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³		
					TRACKER #2	NIOSH	LUMEX #1
4/18/2002	Fresh mercury (2.4353 grams) was placed in a 1x1 inch plastic weighing boat. Fans were left on and connecting door left open. Bead was 1 cm in diameter and had a shine.	4	98.8	34.8	3.0		
		8	104.9	33.7	4.1		
		12	95.3	35.7	3.4		
		16	85.8	37.1	2.5		
		20	81.0	37.0	1.6		
		24	88.1	32.9	1.0		
		28	96.0	35.1	1.2		
		32	100.9	35.8	1.9		
		36	84.6	38.0	1.8		
		40	81.1	39.9	1.2		
		44	81.3	38.2	0.88		
4/20/2002	Above experiment continued.	48	83.7	36.9	0.79		
		52	81.9	37.5	0.75		
		56	82.1	37.6	0.70		
		60	81.7	35.1	0.59		
		64	81.4	33.2	0.49		
		68	81.4	29.7	0.34		
		72	82.4	27.3	0.26		
		76	83.1	27.4	0.31		
		80			0.35		
		84			0.29		
		88			0.27		
	Final weight 2.4337gms	92			0.22		
		96			0.22		
4/22/2003	Experiment continued	100	80.4	31.8	0.62		
		104	82.0	33.2	0.51		
		108	81.0	32.2	0.54		
		112	80.0	27.0	0.32		
		116	80.2	25.3	0.25		
		120	86.7	22.2	0.14		
	Final weight 2.4343gms	124	85.0	24.4	0.23		
		126	83.7	25.5	0.30		

TABLE A5
Effect of Surface Area Simulation : Experiment 5
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³		
					TRACKER #2	NIOSH	LUMEX #1
5/4/2002	Mercury (8.3869 grams) placed in a	4	86.0	23.8	3.3		
	2 x 2 inch plastic weighing dish.	8	83.0	22.8	2.5		
	Dish placed on carpet in tray.	12	81.2	22.6	1.5		
	Diameter of bead 1.6 cm.	16	81.2	22.6	0.94		
	Fan was turned off.	20	90.2	22.5	1.0		
		24	86.5	24.7	0.99		
		28	83.7	24.0	0.81		
		32	82.2	23.9	0.40		
		36	82.4	23.9	0.24		
		40	82.8	24.8	0.14		
		44	87.3	25.3	0.22		
		48			0.18		
5/5/2002	Fan turned on. Monitoring continued.	52	88.4	25.6	0.42		
		56	82.8	28.1	0.21		
		60	83.7	28.1	0.14		
		64	83.0	28.7	0.14		
		68	90.3	28.6	0.06		
		72	91.8	29.9	0.21		
		76	88.1	28.4	0.33		
		80	82.2	29.0	0.21		
		84	83.1	28.8	0.08		
		88	83.1	30.9	0.12		
	Final weight 8.3809	92	90.1	30.6	ND		
		94	93.6	33.6	0.12		
	Mercury (8.3809 grams) placed in a	4	94.3	34.3	8.7		7.8
	2 x 2 inch plastic weighing dish.	8	88.4	35.8	4.7		4.4
	Dish placed on carpet in tray.	4-8			4.8	8.2	4.1
	Diameter of bead was 1.6 cm.	12	81.9	38.5	2.6		2.2
	Fan was turned on.	8-12			2.5	3.5	2.1
		16	81.3	38.5	1.5		1.5
		12-16			1.5	2.5	1.4
	Final weighing 8.3786	20	89.6	32.6	0.73		0.88
5/7/2002	Loss in weight 0.0023	24	90.5	32.2	0.80		0.79

TRACKER #2 Serial Number 0301/168
LUMEX #1 Serial Number S/N 121
ND = <0.10 µg/m³, Instrument Detection Level

TABLE A6
Surface Area Regeneration Simulation: Experiment 6
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, μg/m^3		
					TRACKER #2	NIOSH	LUMEX #1
5/8/2002	0.9756 grams of mercury placed in a 2x2"	4	82.6	34.5	2.6		2.1
	plastic weighing dish. Mercury bead	8	80.8	32.2	3.6	6.6	3.3
	diameter, 0.5 cm. Dish placed on a	12	80.8	31.7	3.3	6.1	3.0
	mechanical shaker, set to shake for 999	16	80.5	32.1	3.0	5.6	2.7
	minutes at 100 cycles per minute.	20	80.7	32.5	2.3		2.1
	Initial weight 0.9756 grams. Fans on.						
	Final weight 0.9730 g						
	Shaker off						
5/9/2002	Shaker on	4	…	33.8	2.8		2.5
		8	80.8	34.9	3.3	6.2	3.0
		12	81.0	36.0	3.6	6.5	3.2
	Shaker off	16	81.1	36.8	3.8	6.4	3.5
	Initial weight 0.9730 g	20	81.0	37.2	3.4		3.2
	Final weight 0.9694 g	24	92.3	34.1	2.2		2.3
5/10/2002	Shaker on	4	93.6	32.3	5.7		
		8	90.3	30.0	7.2	11	
		12	81.9	28.5	6.4	8.4	
5/11/2002		16	80.7	25.9	4.4	13	
		20	80.9	24.8	2.9		
		24	88.9	23.0	0.79		
		28	92.1	24.6	0.62		
		32	89.2	24.6	0.64		
		36	81.1	25.8	0.52		
		40	80.5	27.6	0.19		
	Initial weight 0.9694 g	44	80.8	28.8	0.16		
	Final weight 0.9568 g	48	80.9	31.1	0.18		
		50	81.1	33.0	0.18		

TRACKER #2 Serial Number 0301/168
LUMEX #1 Serial Number S/N 121

TABLE A6
Surface Area Regeneration Simulation: Experiment 6
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³		
					TRACKER #2	NIOSH	LUMEX #1
5/17/2002	9.6319 grams of mercury placed in a 2x2"						
	plastic weighing dish. Mercury bead	4	93.4	33.6	26		
	diameter, 1.5 cm. Dish placed on a	6	87.7	32.9	29	31	
	mechanical shaker, set to shake for 999	8	83.1	31.9	24	28	
	minutes at 100 cycles per minute.	4-8	85.4	32.4	27	30	
	Fans on.	10	80.7	32.4	20	24	
		12	80.4	34.6	16	20	
		8-12	80.6	33.5	18	22	
		14	81.4	35.1	15	17	
	Shaker turned off.	16	80.6	37.2	15	17	
		12-16	81.0	36.2	15	17	
	Initial weight 9.6319 g	18	82.1	38.2	12		
	Final weight 9.6196 g	20	83.1	37.9	7.6	12	
5/18/2002	Shaker turned off.	24	83.0	37.0	5.6		
		28	81.8	37.0	4.7	6.0	
		32	81.0	33.6	2.8	3.7	
		36	80.6	30.2	1.5	1.9	
		40	80.6	28.4	1.0	1.3	
		44	84.2	28.4	0.94	1.1	
		48	82.8	30.2	0.90	1.2	
		52	82.3	29.4	0.85		
		56	80.7	27.4	0.58		
	Initial weight 9.6196 g	60	80.8	25.4	0.40		
	Final weight 9.6181 g	64	80.6	24.7	0.36		
	Loss in weight 0.0015 g	66	83.1	24.5	0.40		
5/20/2002	Mercury beads shaken, shaker turned off	4	84.0	24.4	3.8		
		8	82.0	24.8	2.1	2.5	
		12	81.6	24.5	1.1	1.3	
		16	80.4	24.4	0.71	0.83	
		20	80.5	23.9	0.46	0.61	
		24	83.4	23.4	0.32	0.44	
		28	84.8	24.8	0.39	0.52	
		32	81.8	25.5	0.44		
	Initial weight 9.6181 g	36	81.6	24.8	0.38		
	Final weight 9.6171 g	40	81.0	24.7	0.24		
	Loss in weight 0.0010 g	44	81.0	24.4	0.19		
		48	83.1	24.3	0.18		10
5/23/2002	The mercury bead was shaken.	4	93.6	25.5	4.7		2.8
		8	95.4	24.5	3.5	4.5	1.9
		12	85.2	26.0	2.4	2.8	1.1
		16	81.4	26.7	1.2	1.4	0.64
		20	81.1	27.5	0.88	1.1	0.50
		24	89.4	27.2	1.3	1.7	0.86
		28	99.0	28.6	3.1	3.7	1.8

TRACKER #2 Serial Number 0301/168

LUMEX #1 Serial Number S/N 121

TABLE A7
Simulation of Ritualistic Mercury Use in a Large Home Room : Experiment 7
Mercury Vapor Monitoring in a Trailer: Large Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m^3			
					Tracker # 1	Tracker # 2	NIOSH	Lumex # 2
11/14/2002	0.9820 gram mercury bead placed in	4	81.8	34.8	1.7	1.9		1.4
	a 1 x 1 inch plastic weighing boat. Door closed.	8	81.9	35.2	1.0	1.2	1.4	0.78
11/15/2002	Fans were left on. Diameter of mercury	12	81.9	35.3	0.31	0.38		0.26
	bead, 0.5 cm. Exp started at 4.05 PM	16	81.6	34.6	0.13	0.18	0.29	0.14
	(1605 hrs)	20	83.0	35.1	0.22	0.30		0.23
		24	83.2	37.3	0.39	0.52		0.36
		28	82.7	35.6	0.28	0.40		0.23
		32	82.2	34.0	*	0.20		0.13
11/16/2002		36	81.9	33.9	*	0.11		0.09
		40	82.4	33.6	*	0.11		0.08
		44	82.5	34.9	*	0.08		0.07
		48	83.1	33.4	*	0.06		0.06
		52	83.8	32.9	*	0.06		0.05
		56	83.5	32.8	*	0.06		0.04
11/17/2002	End of Tracker	60	83.1	34.0	*	0.09		0.05
	Download data and pick up samples	64	83.1	35.7	*	0.10		
	Pump #2 failed, stopped after 1 min.							
	Start again at 9.20 AM (0920 hrs)	68	79.7	36.6	0.03	0.05		0.04
		72	81.3	39.3	0.04	0.12		0.08
		76	81.1	41.1	0.08	0.17	0.16	0.09
		80	81.1	41.2	0.08	0.16	**	0.06
11/18/2002		84	81.0	40.6	0.07	0.14	0.17	0.01
		88	81.0	39.4	0.05	0.14		0.06
		92	81.9	39.5	0.04	0.12		0.10
		96	83.2	40.7	0.13	0.21		0.12
		100	81.3	38.6	0.15	0.28		0.14
		104	80.6	35.3	0.13	0.22		0.12
11/19/2002		108	80.6	32.8	0.17	0.24		0.16
		112	80.7	30.9	0.06	0.17		0.09
		116	81.5	31.2	0.02	0.09		0.08
		120	81.9	33.1	0.06	*		0.08
		124	81.7	33.3	0.04	0.12		0.06
	End of Tracker	128	81.5	33.5	0.04	0.11		
11/20/2002		132	81.2	32.5				
	Download data and pick up samples	136	80.5	31.4				
	All pumps worked	137						
	Start again at 9.21 AM (0921 hrs)	145	83.9	34.8	0.03	0.05	0.12	0.06
		153	82.4	32.7	0.05	0.12	0.10	0.05
11/21/2002		161	81.7	30.2	0.01	0.06	0.07	0.034
		169	83.0	33.5	0.01	0.08	0.08	0.037
		177	83.1	35.2	0.02	0.09	0.10	0.045
11/22/2002		185	83.1	37.1	0.03	0.11		0.055
		193	83.0	39.0	0.05	0.15	0.13	0.07

TABLE A7
Simulation of Ritualistic Mercury Use in a Large Home Room : Experiment 7
Mercury Vapor Monitoring in a Trailer: Large Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³			
					Tracker # 1	Tracker # 2	NIOSH	Lumex # 2
		201	82.1	38.7	0.06	0.16	0.16	0.08
11/23/2002		209	82.3	35.8			0.14	0.065
		209						
	Download data and pick up samples	217	82.4	24.5	0.08	0.15	0.20	0.11
	Start again at 0950 AM	225	81.1	22.4	0.06	0.15	0.14	0.07
11/24/2002		233	80.9	21.5	0.01	0.06	0.08	0.04
		241	83.1	23.5	0.04	0.12		0.08
		249	81.5	22.1	0.02	0.08	0.09	0.04
11/25/2002		257	81.5	20.8	0.01	0.04	0.04	0.02
	Weight of mercury bead 0.9814 g							
	Download data and pickup samples at 0940							
11/25/2002	Add 4.0 gram mercury (4 bead placed each 1.0 g	4	83.1	25.0	4.2	5.0	5.9	3.2
	in a 1 x 1 inch plastic weighing boat).	8	82.4	26.0	2.7	3.3	4.0	2.0
	Fans on. Diameter of mercury	12	82.4	24.8	1.6	2.0	2.4	1.2
11/26/2002	bead, 0.5 cm. Exp. started at 10:39 PM	16	81.7	23.4	1.2	1.4		0.85
	Total wt 0f mercury 5.0508 grams	20	80.9	22.1	0.78	0.94	1.2	0.56
	0.9814, 1.0146, 0.9028, 1.1252, 1.0268	24	81.5	21.0	0.55	0.67		0.41
		28	83.3	21.8	0.57	0.69	0.99	0.43
		32	82.1	21.0	0.54	0.64		0.36
		36	81.2	20.1	0.45	0.57	0.67	0.32
11/27/2002		40	81.3	20.8	0.47	0.59		0.34
		44	80.5	21.6	0.38	0.47	0.58	0.28
		48	81.2	21.9	0.31	0.41		0.25
		52	82.2	23.0	0.34	0.43	0.70	0.26
		56	81.9	22.3	0.29	0.40		0.24
		60	81.2	20.4	0.21	0.31	0.38	0.18
11/28/2002		64	80.4	20.2				0.14
		68	79.1	19.8			0.25	0.12
		72	79.2	19.6				0.12
		76	81.3	20.7			0.29	0.13
		80	80.6	20.5				0.12
		84	80.4	19.3			0.23	0.11
11/29/2002		88	80.3	18.2				0.10
		92	79.6	17.7			0.20	0.09
	Download data and pickup samples @ 0930.	96	79.1	17.7				
	Restarted new pumps and instruments @ 0955.							
		101	81.4	24.6	0.19	0.25	0.46	0.05
		105	80.5	24.9	0.20	0.27	0.34	0.10
		109	80.8	25.1	0.20	0.28	0.38	0.17
11/30/2002		113	80.6	25.6	0.14	0.24		0.14
		117	81.0	25.8	0.14	0.25	0.31	0.13
		121	81.3	26.0	0.09	0.21		0.12

TABLE A7
Simulation of Ritualistic Mercury Use in a Large Home Room : Experiment 7
Mercury Vapor Monitoring in a Trailer: Large Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, μg/m³			
					Tracker # 1	Tracker # 2	NIOSH	Lumex # 2
		125	81.7	26.6	0.11	0.21	0.23	0.11
		129	81.6	27.3	0.11	0.23		0.11
		133	80.5	21.4	0.09	0.17	0.20	0.10
12/1/2002		137	81.3	25.8	0.04	0.11		0.08
		141	81.1	24.4	0.04	0.13	0.15	0.07
		145	81.4	23.0	0.01	0.06		0.06
		149	82.3	22.7	0.02	0.07	0.12	0.06
		153	81.5	21.9	0.03	0.08		0.05
		157	80.4	20.5	0.03	0.07	0.10	0.04
12/2/2002		161	79.8	19.8	ND	0.07		0.04
		165	80.6	19.7			0.07	0.03
		169	80.2	20.3				0.03
		173	80.6	20.7			0.08	0.04
		177	81.0	20.8				0.04
		181	80.5	21.1			0.08	0.04
12/3/2002		185	80.7	21.1				0.03
		189	80.2	19.9			0.07	0.03
		193	75.6	18.7				
	Download data and pickup samples @ 0930.							
	Restarted new pumps and instruments @ 1010.	201	80.3	18.6	0.01	0.04	0.07	0.03
12/4/2002		209	77.0	17.5	ND	0.08	<0.032	0.02
		307	73.4	17.7	ND	0.02	<0.031	0.02
		315	79.9	18.7	ND	ND	<0.039	0.02
12/5/2002		323	80.3	18.6	0.01	0.03	<0.036	0.02
	Stopped @1012.	331	79.9	19.4	ND	0.06	<0.034	0.02
	Download data and weight of mercury bead 1,2, 3,4,5 were 0.9813, 1.0136, 0.9022, 1.1242, 1.0262							
12/5/2002	Add 5.0 gram mercury (5 bead placed each 1.0	8	77.4	22.5	3.1	3.70	4.1	
12/6/2002	g in a 1 x 1 inch plastic weighing boat).	16	79.4	22.0	0.56	0.67	0.77	
	Fans were left on. Diameter of mercury	24	79.7	22.2	0.30	0.41	0.39	
	bead, 0.5 cm. Exp. started at 1100.	32	80.8	23.0	0.29	0.38	0.46	
12/7/2002	Total wt. of mercury 10.3962 grams	40	79.1	22.5	0.15	0.23	0.22	
	Weight of mercury beads, 0.9813, 1.0136, 0.9022,	48	75.8	21.2	0.09	0.18	0.17	
	1.1242, 1.0262, 1.0112, 0.9856, 1.2421,	56	80.5	21.9	0.13	0.19	0.27	
	1.1419, 0.9679	60	80.9	21.5	0.10	0.19		
12/8/2002		64	80.7	21.4			0.36	
		68	79.2	21.5				
		72	79.8	21.5			0.19	
		76	81.4	23.7				
		80	80.8	24.4			0.24	
		84	80.7	23.8				
12/9/2002		88	80.1	22.1			0.10	

TABLE A7
Simulation of Ritualistic Mercury Use in a Large Home Room : Experiment 7
Mercury Vapor Monitoring in a Trailer: Large Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³			
					Tracker # 1	Tracker # 2	NIOSH	Lumex # 2
		92	75.9	20.8				
		96	74.7	20.0			0.07	
		100	80.1	21.5				
		104	79.3	20.6			0.06	
		108	77.5	19.9				
12/10/2002		112	76.5	19.6			<0.037	
		116	76.1	19.5				
	Downloaded data and changed pumps @1100	120	77.2	19.4			<0.034	
	Restated with new pumps @1142. One bead in dish shaken	129	80.7	20.7	0.18	0.24	0.31	0.16
12/11/2002		137	80.4	20.0	0.04	0.11	0.13	0.69
		145	80.7	20.4	0.02	0.06	0.08	0.04
		153	82.1	23.3	0.02	0.07	0.08	0.04
12/12/2002		161	82.8	26.0	0.03	0.08	0.09	0.04
		169	81.1	27.1	0.02	0.08	<0.04	0.04
		177	82.4	28.8	0.03	0.09	0.08	0.04
12/13/2002		185	80.2	26.7	0.02	0.09	<0.032	0.03
		193	80.3	25.8			0.05	0.03
		201	80.9	27.8			0.06	0.03
12/14/2002		209	82.5	29.5			0.06	0.03
		217	81.8	32.0			0.06	0.03
		225	80.8	31.5			0.07	0.03
12/15/2002		233	80.9	29.4			0.05	0.03
		241	81.4	28.0			0.05	0.03
		249	81.7	28.3				
12/16/2002		257	80.8	27.0				
	Mercury weights 0.9811,1.0134, 0.9018, 1.1236,	265	80.8	27.1				
	1.0259, 1.0114, 0.9845, 1.2200, 1.1423, 0.9671	129	80.7	20.7	0.18	0.24	0.3 †	0.16

TRACKER #1 Serial Number 0301/161
TRACKER #2 Serial Number 0301/168
LUMEX #2 Serial Number S/N 176

* Instrument malfunction
** Pump did not activate
ND = <0.10 µg/m³, Instrument Detection Level

† Pump near beads

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³ TRACKER # 2	NIOSH
6/10/2002	Seven mercury beads individually placed 1x1 in. plastic weighing dish.	2	89.5	42.4	13	
	Diameter of bead, 0.5 cm each. Total mercury weight 7.0511 grams.	4	92.3	43.6	12	
	Weight of beads: 1.0024, 1.0666, 0.9256, 0.9068, 1.0254, 1.0311, 1.0932	6	94.9	42.9	7.2	
	Monitored from June10 to June 17. Fans on.	8	95.2	42.0	4.2	
		10	90.7	42.6	2.9	
		12	85.6	43.3	2.4	
		14	81.0	44.0	1.7	
		16	77.5	45.3	1.2	
6/11/2002		18	74.8	46.7	1.2	
		20	72.8	48.0	1.5	
		22	74.1	47.6	1.5	
		24	80.9	45.4	1.4	
		26	90.4	45.8	3.5	
		28	96.9	46.4	4.4	
		30	101.5	45.5	4.4	
		32	102.2	44.7	3.6	
		34	98.8	45.0	3.0	
		36	94.3	46.7	2.2	
		38	90.2	48.4	1.8	
6/12/2002		40	86.9	49.1	1.6	
		42	84.3	49.3	1.4	
		44	82.1	49.8	1.2	
		46	82.8	49.0	1.1	
		48	91.1	43.3	0.76	
		50	97.1	45.7	2.4	
		52	100.6	45.3	2.8	
		54	100.5	46.1	2.4	
		56	93.3	53.2	2.0	
		58	90.1	55.8	1.9	
		60	87.4	57.4	2.0	
		62	84.5	58.0	1.9	
6/13/2002		64	79.9	57.8	1.6	
		66	76.1	57.0	1.4	
		68	73.3	56.7	1.3	
		70	72.1	56.1	1.3	
		72	72.8	55.3	1.3	
		74	75.6	54.1	3.2	
		76	78.6	52.9	3.3	
		78	80.1	52.6	2.4	
		80	78.0	53.7	1.6	
		82	75.3	54.6	1.3	
		84	73.0	55.4	1.0	
		86	71.3	56.1	0.72	
6/14/2002		88	70.1	56.8	0.57	
		90	69.2	57.8	0.51	
		92	68.2	59.2	0.48	
		94	67.7	60.4	0.42	
		96	67.4	61.4	0.37	

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³ TRACKER # 2	NIOSH
		98			1.4	
		100			1.1	
		102			0.90	
		104			0.82	
		106			0.87	
		108			0.93	
		110			0.99	
6/15/2002		112			0.98	
		114			0.92	
		116			0.80	
		118			0.80	
		120			0.80	
		122	67.4	68.9	2.4	
		124	69.2	66.0	3.3	
		126	72.1	64.7	3.1	
		128	72.8	65.2	2.9	
		130	72.3	65.4	2.7	
		132	70.9	65.7	2.4	
		134	69.6	65.8	2.0	
6/16/2002		136	68.4	66.1	1.8	
		138	67.2	66.1	1.7	
		140	66.2	65.5	1.6	
		142	67.3	64.6	1.6	
		144	72.4	59.7	1.8	
		146	78.1	60.7	3.0	
		148	84.3	60.3	4.0	
		150	88.1	57.5	3.7	
		152	88.3	56.1	3.3	
		154	85.2	55.9	2.9	
		156	81.5	56.3	2.4	
		158	78.0	56.3	1.8	
6/17/2002		160	75.3	55.7	1.5	
		162	72.7	55.9	1.2	
		164	70.3	56.5	0.93	
		166	73.3	54.1	0.75	
	Restart monitoring after7 days; 168 hours.	168	84.9	47.7	1.1	
6/17/2002	Total weight of mercury 7.0391 grams.	172	88.9	48.9	10	
		174	91.9	49.2	11	
		176	92.9	47.6	8.5	
		178	91.5	46.8	6.4	
		180	87.3	46.7	4.6	
		182	82.2	47.2	3.2	
		184	78.0	47.4	2.2	
6/18/2002		186	74.7	48.3	1.7	
		188	71.6	48.9	1.4	
		190	69.2	49.5	1.0	
		192	73.1	47.2	0.77	
		194	87.7	39.0	1.0	

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³ TRACKER # 2	NIOSH
		196	88.5	44.4	1.6	
		198	92.7	44.2	2.1	
		200	95.4	43.0	2.5	
		202	94.3	42.4	2.4	
		204	89.3	42.9	1.8	
		206	83.5	46.3	1.5	
		208	78.9	48.1	1.1	
6/19/2002		210	75.5	49.3	0.89	
		212	73.2	50.2	0.78	
		214	71.9	51.8	0.72	
		216	73.0	51.9	0.65	
		218	84.6	44.6	0.65	
		220	83.2	51.3	1.4	
		222	86.3	51.1	1.7	
		224	88.5	50.2	1.8	
		226	90.7	48.5	1.8	
		228	87.3	49.3	1.7	
		230	82.7	50.5	1.5	
		232	78.6	51.2	1.2	
6/20/2002		234	75.3	52.0	0.88	
		236	72.7	52.8	0.73	
		238	70.7	53.4	0.66	
		240	73.6	51.5	0.54	
		242	86.2	45.5	0.77	
		244	87.9	47.8	1.2	
		246	90.8	47.0	1.3	
		248	92.7	45.5	1.2	
		250	92.0	45.1	1.0	
		252	88.3	46.0	1.0	
		254	83.8	46.7	1.0	
		256	79.5	48.3	0.78	
6/21/2002		258	76.1	49.7	0.63	
		260	73.4	50.7	0.59	
		262	71.5	51.4	0.57	
		264	74.7	49.6	0.39	
		266	86.3	44.3	0.52	
		268	90.2	46.9	0.85	
		270	94.4	46.9	1.2	
		272	96.7	45.1	1.4	
		274	97.7	43.1	1.3	
		276	93.4	43.4	1.2	
		278	88.2	44.1	1.1	
		280	83.5	45.0	0.94	
		282	80.0	45.9	0.70	
6/22/2002		284	77.3	46.8	0.58	
		286	75.1	47.9	0.53	
		288	75.8	47.5	0.43	
		290	87.0	42.2	0.28	

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³ TRACKER # 2	NIOSH
		292	92.3	44.5	0.30	
		294	97.4	44.9	0.75	
		296	100.7	43.9	1.1	
		298	101.2	42.7	1.2	
		300	97.5	42.8	1.2	
		302	92.6	43.4	1.0	
		304	88.1	44.3	0.97	
		306	84.3	44.5	0.82	
6/23/2002		308	80.9	44.5	0.65	
		310	78.1	45.4	0.53	
		312	78.5	45.4	0.39	
		314	87.5	41.6	0.25	
		316	93.7	43.7	0.28	
		318	98.8	43.7	0.67	
		320	101.9	42.8	0.92	
		322	101.4	42.9	1.1	
		324	97.6	43.7	1.1	
		326	93.4	44.2	1.0	
		328	89.8	44.9	0.92	
6/24/2002		330	86.6	46.3	0.80	
		332	83.9	47.2	0.69	
		334	82.0	48.0	0.64	
		336	84.0	46.4	0.45	
		338	95.3	41.8	0.21	
		340	99.2	44.4	0.53	
		342	103.2	44.3	0.85	
		344	103.6	44.2	0.98	
		346	102.8	44.0	1.1	
		348	99.3	44.5	1.1	
		350	95.3	45.1	1.0	
		352	92.2	46.3	0.95	
6/25/2002		354	89.5	47.4	0.85	
		356	87.3	47.6	0.75	
		358	85.5	48.3	0.66	
	15 days; 362 hours.	360	86.2	48.4	0.47	
	Total weight of mercury 7.0347 grams	362	89.3	47.2	0.31	
7/2/2002	22 days (528 hours) Total weight of mercury 7.0296 grams	528			NM	
7/9/2002	29 days (696 hours) Total weight of mercury 7.0128 grams	696			NM	
7/16/2002	36 days (864 hours) Total weight of mercury 7.0103 grams	864			NM	
7/16/2002	Seven mercury beads individually placed 1x1 in. plastic weighing dish.	2	98.3	35.8	12	
	Diameter of bead was 0.5 cm each. Total mercury weight 7.0043 grams.	4	101.1	34.7	13	
	Weight of beads: 0.9982, 1.0637, 0.9235, 0.8965, 1.0228, 1.0238, 1.0758	6	103.7	32.5	10	
	Fans on.	8	100.8	32.7	7.5	
		10	96.2	32.8	6.1	
		12	91.7	33.1	4.8	
		4-12			7.1	7.87
		14	87.7	33.4	3.5	
7/17/2002		16	84.0	33.9	2.7	

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. ^{O}F	% RH	CONCENTRATION, µg/m³ TRACKER # 2	CONCENTRATION, µg/m³ NIOSH
		18	80.8	34.7	2.0	
		20	79.2	36.1	1.6	
		12-20			2.5	2.71
		22	84.2	35.5	1.6	
		24	95.3	32.5	2.0	
		26	99.2	34.8	3.5	
		28	103.9	34.8	4.8	
		20-28			3.0	3.76
		30	107.9	34.4	5.7	
		32	107.3	35.1	6.4	
		34	104.0	35.7	6.3	
		36	100.7	36.4	5.4	
		28-36			6.0	8.81
		38	97.5	37.6	4.3	
7/18/2002		40	94.6	38.4	3.6	
		42	92.0	39.2	3.1	
		44	89.8	40.1	2.6	
		36-44			3.4	3.91
		46	92.4	38.7	2.5	
		48	101.0	34.1	3.0	
7/18/2002		51	105.8	37.0	2.6	
		53	106.2	37.0	3.9	
		55	105.8	36.6	4.1	
		57	104.0	36.6	4.0	
		59	100.5	37.1	3.3	
		61	96.8	38.0	2.6	
		63	93.7	39.6	2.1	
		55-63			4.1	4.95
7/19/2002		65	91.2	40.5	1.9	
		67	88.9	41.9	1.7	
		69	87.4	42.7	1.6	
		71	89.9	41.5	1.4	
		63-71			2.8	2.6
		73	95.6	40.7	1.6	
		75	100.4	40.8	2.3	
		77	100.7	41.9	2.8	
		79	98.0	43.4	2.6	
		71-79			2.0	2.58
		81	95.5	46.8	2.4	
		83	89.4	59.9	2.6	
		85	85.8	64.7	2.9	
		87	83.2	67.2	3.4	
		79-87	81.2	69.0	2.6	3.21
7/20/2002		89	81.2	69.0	3.8	
		91	79.7	70.3	4.0	
		93	78.7	71.1	4.1	
	Total mercury weight 6.9974 grams	95	82.4	68.2	4.3	
		87-85			3.8	4.17

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³ TRACKER # 2	NIOSH
	End after 4days; 97 hours.	97	94.1	53.4	4	
7/30/2002	Seven mercury beads individually placed 1x1 in. plastic weighing dish.	2	103.0	48.0	13	
	Diameter of bead: 0.5 cm each. Total mercury weight 6.9842 grams.	4	104.6	46.9	16	
	Monitored from July 30 to August 5. Fans on.	6	107.2	44.8	15	
		8	104.3	44.4	11	
		10	99.4	44.3	8.3	
		12	95.2	44.5	6.2	
		4-12			9.9	15
		14	91.6	45.0	4.7	
7/31/2002		16	88.4	45.7	3.7	
		18	85.6	46.5	3.0	
		20	83.2	47.2	2.4	
		12-20			3.4	4.8
		22	89.2	44.3	2.1	
		24	104.9	37.8	3.0	
		26	103.2	41.7	3.8	
		28	106.0	40.1	4.5	
		20-28			3.4	5.1
		30	107.9	38.5	5.1	
		32	105.5	38.2	5.1	
		34	101.3	38.7	4.5	
		36	96.8	40.2	3.5	
		28-36			4.5	6.9
		38	93.1	41.7	2.6	
8/1/2002		40	89.7	43.3	2.1	
		42	87.0	44.2	2.0	
		44	85.5	44.4	1.9	
		36-44			2.1	3.1
	Total mercury wt: 6.9787grams	46	89.0	42.9	1.7	

TRACKER #2 Serial Number 0301/168
NM: Not Measured

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS			CONCENTRATION, µg/m3	
			TEMP. ^{O}F	% RH	TRACKER # 2	NIOSH
8/5/2002	A mercury bead placed in a plastic weighing dish. Weight of	2	97.2	54.8	4.7	
	mercury bead 1.1058 grams and diameter of 0.5 cm.	4	100.7	53.3	7.4	
	Monitored from August 5 to August 8. Fans on.	6	101.4	52.5	6.7	
		8	100.5	52.4	5.5	
		10	97.5	52.2	4.4	
		12	94.3	52.6	3.5	
		4-12			5.1	6.0
		14	91.7	53.1	2.8	
8/6/2002		16	89.6	54.0	2.5	
		18	87.2	54.0	2.1	
		20	84.6	52.7	1.8	
		12-20			2.3	2.7
		22	88.6	48.7	0.95	
		24	98.7	38.9	0.74	
		26	95.2	41.8	0.90	
		28	96.0	40.2	1.1	
		20-28			0.91	1.4
		30	96.9	38.6	1.1	
		32	93.6	38.4	1.1	
		34	88.2	38.7	1.1	
		28-36			1.1	1.1
		36	83.5	39.1	1.0	
		38	80.0	39.7	0.68	
8/7/2002		40	77.2	40.7	0.51	
		42	75.1	41.8	0.43	
		36-44			0.50	0.45
		44	73.6	42.6	0.36	
	46 hours emission - Mercury wt: 1.1050 grams	46	78.8	40.6	0.16	
8/12/2002	A mercury bead placed in a plastic weighing dish. Weight of	2	98.6	43.6	5.7	
	mercury bead 1.1446 grams and diameter of 0.5 cm.	4	105.0	42.4	7.4	
	Monitored from August 12 to August 14.	6	106.9	41.2	5.3	
		8	107.2	40.0	4.1	
		10	104.0	40.7	3.1	
		12	99.8	41.6	2.5	
		4-12			3.7	4.7
		14	96.1	41.9	2.1	
8/13/2002		16	93.0	42.1	1.8	
		18	93.0	42.1	1.6	
		20	87.9	44.1	1.5	
		12-20			1.7	2.0
		22	87.8	44.1	1.6	
		24	96.4	40.4	2.0	
		26	96.4	40.4	2.5	
		28	107.9	40.5	2.5	
		20-28			2.2	2.9
		30	110.8	39.0	2.5	
		32	110.4	37.9	2.2	
		34	106.2	38.0	1.9	

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS			CONCENTRATION, µg/m3	
			TEMP. °F	% RH	TRACKER # 2	NIOSH
		36	101.5	39.3	1.5	
		28-36			2.0	2.6
		38	97.4	39.9	1.0	
8/14/2002		40	94.1	40.4	0.93	
		42	91.4	41.3	0.79	
		44	88.8	42.4	0.66	
		36-44			0.85	0.96
		46	88.8	42.6	0.55	
	47 hours emission - Mercury wt: 1.1432 grams	48	96.2	40.8	0.40	
8/14/2002	A mercury bead placed in a plastic weighing dish. Weight of	2	101.5	43.9	4.4	
	mercury bead 1.1256 grams and diameter of 0.5 cm.	4	107.0	42.4	5.6	
	Monitored from August 14 to August 16. Fans on.	6	110.0	40.8	4.8	
		8	109.6	39.5	3.4	
		10	105.4	39.4	2.2	
		12	100.5	39.7	1.8	
		4-12			3.1	3.8
		14	96.0	39.8	1.5	
		16	92.0	40.9	1.3	
8/15/2002		18	89.1	43.3	1.2	
		20	87.4	45.2	1.4	
		12-20			1.3	1.5
		22	86.8	46.4	1.6	
		24	95.4	42.8	1.7	
		26	101.0	43.3	1.9	
		28	105.8	42.9	2.0	
		20-28			1.8	2.5
		30	108.2	40.7	2.0	
		32	108.0	40.1	1.9	
		34	104.3	41.6	1.6	
		36	100.1	43.2	1.5	
		28-36			1.8	2.2
		38	96.7	44.8	1.4	
		40	93.9	46.4	1.1	
8/16/2002		42	91.9	47.6	1.1	
		44	90.4	48.7	1.2	
		36-44			1.2	1.7
		46	89.4	49.5	1.2	
	48 hours emission - Mercury wt: 1.1243 grams	48	89.7	49.4	1.3	

TRACKER #2 Serial Number 0301/168

TABLE A8
Mercury Vapor Emission Rate: Experiment 8
Mercury Emission Rate

DATE	EXPERIMENT CONDITIONS	HOURS			CONCENTRATION, µg/m3	
			TEMP. °F	% RH	LUMEX # 2	NIOSH
8/19/2002	A mercury bead placed in a plastic weighing dish. Weight of mercury bead 1.0387 grams and diameter of 0.5 cm. Monitored from August 19 to August 20. Fans on.	2	101.5	40.1	2.9	
		4	105.8	40.3	3.4	
		6	108.6	39.3	3.1	
		8	107.2	38.8	2.8	
		8-12			1.9	3.9
		10	103.3	38.9	2.3	
		12	98.4	39.7	1.5	
		14	94.6	41.8	1.1	
8/20/2002		16	91.8	43.4	0.96	
		12-16			1.0	2.1
		18	90.1	44.3	1.0	
		20	86.2	50.9	0.94	
		16-20			0.97	1.9
		22	84.8	52.8	0.74	
	22 hours emission - Mercury wt. 1.0380					

LUMEX #2 Serial Number S/N 176

TABLE A9
Investigation to Determine Significant Differences Between Lumex and NIOSH: Experiment 9
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³			
					TRACKER # 1	TRACKER # 2	NIOSH	LUMEX # 2
12/18/2002	Place 10.0 gram mercury (10 beads placed each,	4	81.0	19.1	7.2	8.4		5.5
	1.0 gm in a 1 x 1 inch plastic weighing boat).	8	88.2	18.3	3.5	4.1	6.9	2.6
	Fans were left on. Diameter of mercury	12	86.9	17.9	1.6	1.9		1.1
12/19/2002	bead, 5cm. Exp started at 0900.	16	87.1	17.6	1.2	1.4	2.0	0.78
		20	87.1	17.5	1.0	1.2		0.72
	Weight of mercury beads: 1.1161; 1.2460; 1.0356;	24	87.9	18.2	1.2	1.4	1.6	0.81
	1.0741; 0.8714; 1.1427; 1.0197; 1.0704; 1.0849	28	87.8	20.1	1.6	2.0		*
	1.2025	32	88.2	21.6	2.1	2.5	2.8	
	Total weight: 10.8634	36	88.5	22.3	2.3	2.7		
12/20/2002		40	88.1	23.6	2.1	2.5	3.3	
		44	88.5	25.1	2.2	2.6		
		48	88.8	27.9	3.1	3.7	3.9	
		52	89.4	32.0	2.6	3.1		
		56	90.3	32.4	2.2	2.6	**	
		60	88.7	28.9	1.4	1.7		
12/21/2002		64	87.7	25.7	0.96	1.2	1.8	
		68	87.9	23.9				
		72	87.7	23.2			1.6	
		76	89.0	22.9				
		80	88.1	22.1			1.2	
		84	88.0	22.6				
12/22/2002		88	87.7	21.9			**	
		92	87.6	21.5				
		96	87.5	21.2			0.50	
		100	88.8	21.4				
		104	89.7	22.5			0.49	
		108	88.3	22.9				
12/23/2002		112	88.4	23.2			0.64	
	Tracker reading near beads was 0.32 µg/m³	116	87.8	21.8				
	after 120 hours.	120	88.0	20.6			0.40	

TABLE A9
Investigation to Determine Significant Differences Between Lumex and NIOSH: Experiment 9
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³			
					TRACKER # 1	TRACKER # 2	NIOSH	LUMEX # 2
	Download data and weighed the beads.	121					7.2 †	
	Started at 10.24 AM.	125	77.4	16.7	10.3	12.3		7.5
	1.1102; 1.2429; 1.0300; 1.0662; 0.8710;	129	77.4	16.4	4.6	5.5	13.0	3.3
	1.1418; 1.0143; 1.0677; 1.0700; 1.2002	133	76.8	15.9	2.5	3.0		1.8
12/24/2002	Total 10.8143	137	77.4	15.6	1.9	2.2	**	1.3
		141	76.7	15.1	1.7	2.0		1.2
		145	77.5	14.7	1.6	1.9	2.2	1.2
		149	77.2	15.3	1.7	2.0		1.2
		153	76.9	15.0	1.6	1.9	2.1	1.1
		157	76.8	15.0	1.4	1.7		1.0
12/25/2002		161	76.8	16.3	1.3	1.6	1.8	0.95
		165	76.9	17.6	1.1	1.3		0.78
		169	77.4	19.1	1.0	1.2	1.4	0.76
		173	77.1	21.5	0.89	1.1		0.66
		177	76.6	20.8	0.71	0.85	1.0	0.50
		181	77.0	20.5	0.82	0.97		0.59
12/26/2002		185	77.2	19.6	0.75	0.92	1.0	0.56
		189	76.6	18.5				0.56
		193	76.9	17.8			1.2	0.64
		197	77.3	18.0				0.70
		201	78.2	18.4			0.44	0.73
		205	77.4	18.4				0.42
12/27/2002	1.1129; 1.2446; 1.0304; 1.0728; 0.8709; 1.1411;	209	77.1	18.1			0.65	0.29
	1.0180; 1.0697; 1.0836; 1.2000	213	76.8	17.7				0.27
	Total= 10.8440	217	76.8	17.5			0.80	0.43

TRACKER #1 Serial Number 0301/161
TRACKER #2 Serial Number 0301/168
LUMEX #2 Serial Number S/N 176

* Instrument malfunction
** Pump did not activate
ND = <0.10 µg/m³, Instrument Detection Level

† Pump near beads

TABLE A10
Investigation to Determine Significant Differences Between Lumex and NIOSH: Experiment 10
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³					
					TRACKER # 1	TRACKER # 2	NIOSH	LUMEX # 2	LUMEX # 3	LUMEX # 4
3/2/2003	Place 2.0 gram mercury as a bead on the carpet	6				Data lost				
	Fans were left on. Started at 1135.	12				Could not				
3/3/2003		18				locate				
		24				downloaded				
		25				file				
	Start pumps at 1235.	27	81.9	15.7					3.40	
		33	82.5	13.3			1.6, 1.7		1.3	
3/4/2003		39	81.7	11.6			0.77, 0.82		0.64	
		45	80.5	11.3			0.75, 0.74		0.59	
		51	82.3	13.0			1.0, 1.0		0.84	
		53								
	Start pumps at 1607	55	77.9	21.2		1.3		1.4		
		59	77.4	21.3		1.4	1.6	1.3		
3/5/2003		65	77.2	22.4		1.7	1.9	1.5		
		71	77.8	25.7		3.4	3.8	3.0		
		77	78.4	29.4		4.4	4.7	3.9		
		83	78.2	30.8		3.2	3.4	2.8		
3/6/2003		89	77.7	29.2		1.9	2.1	1.7		
		95	77.0	27.1		1.2	1.4			
		101	78.2	25.1		0.89	1.0			
		107	77.2	23.3		0.70	0.76			
3/7/2003		113	76.0	21.3		0.51	0.58			
		117	75.2	20.1						
		119								
	Start pumps at 0930	121	77.7	21.9	1.2			Instrument		
		125	77.1	24.2	0.81		0.92	Failed		
		131	77.0	23.9	0.65		0.72	in the first		
3/8/2003		137	76.8	23.5	0.51		0.56	zeroing		
		143	76.9	23.6	0.52		0.54	period		
		149	77.5	31.6	0.72		0.72			
		155	77.7	30.2	0.69		0.72			
3/9/2003		161	77.5	27.3	0.66		0.72			
		167	78.1	28.2	0.67		0.74			
		173	79.8	29.9	0.76		0.82			
		179	78.7	25.3	0.54		0.60			
3/10/2003		185	76.9	20.9						
		190	76.5	19.0						
3/11/2003		214								
3/12/2003		238								
3/13/2003		262								
3/14/2003		286								
3/15/2003		310								
3/16/2003		334								
3/17/2003		360								
3/17/2003		362	81.5	37.9	1.4	1.2		1.3		
		366	84.9	37.2	3.3	3.4	4.0	3.1		
		372	79.7	38.1	1.9	1.9	2.1	1.6		

TABLE A10
Investigation to Determine Significant Differences Between Lumex and NIOSH: Experiment 10
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m³					
					TRACKER # 1	TRACKER # 2	NIOSH	LUMEX # 2	LUMEX # 3	LUMEX # 4
3/18/2003		378	78.2	37.0	1.2	1.1	1.4	1.0		
	At 1000 hrs the computer for Lumex showed	384	78.1	36.2	0.89	0.90	0.96	*		
	malfunction. Data not collected from 0437	390	80.3	36.5	0.74	0.77	0.87	0.70		
	o 1037.	396	77.9	33.4	0.54	0.55	0.61	0.51		
3/19/2003		402	77.9	31.4	0.38	0.40	0.45	0.37		
		408	78.1	28.7	0.32	0.33	0.37	0.30		
		414	78.3	27.2	0.28	0.29	0.32	0.26		
		420	78.0	25.3	0.21	0.22	0.24	0.21		
3/20/2003		437								
	Start pumps at 1530	439	78.0	30.8	1.6	1.5				*
		443	78.3	31.5	1.1	1.1	1.3			*
3/21/2003		449	78.0	37.0	1.1	1.1				*
		455	78.0	40.6	1.6	1.6	1.7			*
		461	79.6	43.1	2.5	2.5				2.9
		467	78.7	48.4	2.4	2.4	2.8			2.7
3/22/2003		473	78.5	46.1	2.1	2.1				2.3
		479	79.5	42.7	1.8	1.8	1.9			2.0
		485	86.9	42.4	2.1	2.2	2.4			2.5
		491	80.9	37.9	1.6	1.6				*
3/23/2003		497	77.9	34.4	0.83	0.80	0.86			*
		503	78.2	32.0						*
		509	83.6	32.8						*
		515	79.4	32.4						*
		517	78.3	30.9						*
3/24/2003		523	77.8	30.2			0.47			*
		529	78.9	30.4						0.60 **
		533	82.6	31.0						
	Start monitoring									
		536	77.8	31.6	1.1	1.2				1.1 ***
		540	78.3	29.8	0.73	0.74				0.83
3/25/2003		544	78.1	28.9	0.58	0.62				0.68
		548	80.1	31.5	0.51	0.56				0.64
		552	79.3	30.1	0.68	0.66				0.79
		556	85.2	31.6	0.70	0.76				1.0
	Start pumps at 1450.	558	85.6	32.2	0.72	0.70				0.82
		562	80.3	31.7	0.67	0.71	0.59			0.58
3/26/2003		566	77.7	30.4	0.38	0.42	0.40			0.43
		570	77.8	29.5	0.36	0.42	0.37			0.39
		574	77.6	30.6	0.35	0.33	0.32			0.39
		578	84.6	32.6	0.25	0.30	0.43			0.49
		582	86.8	33.4	0.54	0.58	0.60			0.64
		586	78.8	34.1	0.50	0.52	0.35			0.80
3/27/2003		590	77.8	33.5	0.42	0.44				0.43
		594	77.6	32.1	0.31	0.36				0.35
		598	77.7	31.1						
	Monitoring started at 0900.	599								
		603	82.2	32.2	0.69	0.67				0.94
		607	84.6	32.5	0.92	0.94				1.1
		611	78.9	31.5	0.82	0.81				0.78

TABLE A10
Investigation to Determine Significant Differences Between Lumex and NIOSH: Experiment 10
Mercury Vapor Monitoring in a Trailer: Small Room

DATE	EXPERIMENT CONDITIONS	HOURS	TEMP. °F	% RH	CONCENTRATION, µg/m^3					
					TRACKER # 1	TRACKER # 2	NIOSH	LUMEX # 2	LUMEX # 3	LUMEX # 4
3/28/2003		615	78.0	29.5	0.51	0.53				0.56
		619	77.9	29.0	0.48	0.49				0.54
		623	77.6	29.4	0.37	0.46				0.52
		627	79.3	30.8	0.46	0.48				
		631	78.0	32.0	0.39	0.43				
		635	78.1	32.8	0.34	0.33				
3/29/2003		639	78.5	33.9	0.30	0.32				
		643	78.5	36.1	0.36	0.37				
		647	77.6	38.3	0.39	0.44				
		651	79.3	41.3	0.39	0.41				
		655	84.4	42.5	0.28	0.37				
3/30/2003		659	79.9	47.3	0.54	0.58				

Lumex #2 Serial Number SN176 (EPA unit)
New software was installed.
Calibration Factor: 843

Lumex # 3 Serial Number SN 215 (on loan from Lumex)
New software was installed.
Calibration Factor: 696

Lumex # 4 Serial Number SN 188 (EPA unit)
New software was installed.
Laboratory Calibration Factor: 938

TRACKER #1 Serial Number 0301/161
Calibration Factor 1.40

TRACKER #2 Serial Number 0301/168
Calibration Factor 1.37

* Computer malfunction
shut off between 0437 to 1020

** Sampled between 0849-1449
*** Sampled between 1710-1850

APPENDIX B
Excel Spreadsheet for Predicting Average Mercury Concentration as a Function of Hours of Exposure

Ritualistic Use of Mercury – Simulation:
A Preliminary Investigation of Metallic Mercury Vapor
Fate and Transport in a Trailer

Mercury Concentration Prediction Model:

User Entered Parameters

Room volume (cubic meters)	**200**
Weight of mercury spilled (grams)	**10**
Mercury average droplet diameter (centimeters)	**0.5**
Number of hours exposure (minimum 24; maximum 860)	**860**
Air exchange rate (# of room exchanges per hour)	**1**

Predicted Concentration (µg/m^3)

Predicted Average Concentration for 860 hours exposure	**0.2**

PREDICTED AVERAGE MERCURY CONCENTRATIONS:
24-HOUR TO 4-WEEK (28-DAY) PERIODS

Exposure Period	Exposure Hours	Model Prediction: Average Concentration for Exposure Period $\mu g/m^3$
1 day	24	1.5
2 days	48	1.1
3 days	72	0.7
4 days	96	0.6
5 days	120	0.4
6 days	144	0.3
7 days	168	0.3
14 days	336	0.2
21 days	504	0.2
28 days	672	0.2

User-entered parameters:

Room volume (cubic meters): 200
Weight of mercury (grams): 10
Mercury average droplet diameter (centimeters): 0.5
Air exchange rate (room exchanges per hour): 1